NOTES

ON SOME OF THE

DEVELOPMENTAL AND FUNCTIONAL RELATIONS

OF

CERTAIN PORTIONS OF THE CRANIUM.

SELECTED BY

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FROM

The Lectures on Anatomy

DELIVERED AT GUY'S HOSPITAL

BY

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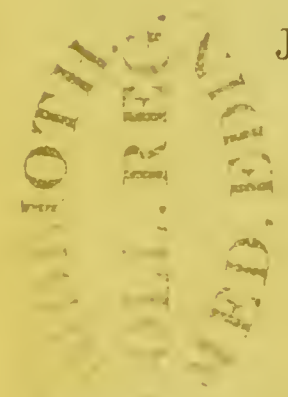

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PREFACE.

The Notes occupying the following pages were selected from Mr. Hilton's Lectures on the Bones of the Head, and arranged for publication in compliance with a desire that was frequently being expressed by those who had heard them.

They were written and originally intended for publication in the Guy's Hospital Reports; and the first half of them appeared in that journal for October, 1853. On account of the recent demise, however, of this periodical, their completion under the form commenced was prevented, and, after a careful revision under Mr. Hilton's superintendence, the whole of them have been placed together, and appear in the present volume.

F. W. P.

Guy's Hospital, November, 1854.

THE

BONES OF THE HEAD

CONSIDERED IN RELATION TO THEIR

FUNCTIONAL AND ANATOMICAL ASSOCIATIONS.

In entering upon the osteology of the cranium, we approach a subject that is not unjustly regarded by the student as one of the most irksome and difficult that he has to encounter in the whole course of his anatomical studies. Of all the bones, none possess so complex a configuration and so intricate an arrangement as those of the cranium—a complexity and intricacy that depend on the numerous and varied functions of the surrounding structures, with which they are placed in the most close and intimate relation. No one, I imagine, possessing or impressed with a just conception of Nature's universal precision in adapting means to ends, can for a moment hesitate to admit that each process of bone; whether belonging to the exterior or to the interior of the skull, and however at first sight apparently insignificant in character; is developed for some especial purpose, or to carry out some especial design. Now, it is to an inquiry into this intention or design that I wish most particularly to direct your attention; and I think we shall find, as we proceed, that it leads to some important and exceedingly interesting considerations, and at the same time divests the study of the cranial bones of that dry detail which otherwise belongs to their simple anatomical description.

Whilst the bones of the extremities are constructed for support and mobility,—those of the trunk for support, mobility, and the protection of their contained viscera,—the cranium, regarded in its primary idea, seems essentially designed for affording security to the delicate and important organ it encloses ; for which object there is a steadily advancing process of development, continued through the earlier and middle periods of life, until it may be said to have attained its final form or a state of perfection ;—that is, when all the separable portions of which it consisted in youth have become consolidated into one bone.

In consequence of this progressive change, the anatomy of the skull necessarily varies with the different periods of life at which it is examined. What is at one time an insulated mass of bone becomes at another and more advanced period firmly united, and continuous with the portions surrounding it. On taking, for example, the cranium at the commencement of extra-uterine life, the frontal bone consists of two, and the occipital of four distinct or discontinuous portions ; whilst at a later period these become respectively consolidated into individual bones, each presenting an uninterrupted extension of osseous structure. Again, to take the cranium at a still later period, the osseous masses that are conventionally regarded as separate cranial bones, become themselves united and consolidated with each other. The sphenoid and occipital bones, for instance, in early youth, exist as separate and independent segments ; but at a more advanced age, they become so firmly united together at the basilar process, as to require artificial division with the saw, even whilst the other segments of the cranium are still easily separable from

each other. The sphenoid and occipital, in fact, at this period constitute as much a single bone as any of the rest, and might consequently not unjustifiably be denominated the spheno-occipital bone.

It is therefore evident that the generally received anatomical division of the cranium into a certain number of bones is an artificial and arbitrary separation, corresponding only with a very transitory period of human existence; and that during the progression towards consolidation (which is steadily but constantly advancing), no precise anatomical division can be made which shall exactly coincide for two separate or distant periods. Although, therefore, I shall incidentally allude to the separate bones for the purpose of enabling you to identify the parts of the skull to which I am referring; yet it is my intention to advert to the anatomy of the cranium at that period of life—the adult period—when all the separable portions of which it consisted in youth have become consolidated or united into one mass, that may not unaptly be termed the *cranio-facial* bone; and when it may be thus regarded as having attained its most perfect condition. A precedent for such an arrangement may be found, in the course that is adopted by anatomists with regard to the description of the *os innominatum*. This bone, although with the attainment of adult age it becomes consolidated into one mass, yet the separate parts of which it was formerly composed are still individualised by retaining the distinct names—ilium, ischium, and pubes—that were attached to them when they existed as independent and isolated bones.

The order of this progressive union or consolidation of the cranial segments seems to bear an intimate relation to the completion or development of the con-

tiguous portions of the brain. The osseous structure thus attains its most efficient condition for carrying out its primary and especial design—security ; cotemporaneously with the completion or perfection of the organ, which it is intended to protect.

It is, if we reflect on it, a necessary condition that consolidation should not be completed till such time as the growth of the brain shall have attained its maximum. For as the cranial bones grow through the medium of the membranous structure that divides them ; so soon as complete union is effected, no further increase in the capacity of the cranium can take place. But, as soon as the cerebral structures have attained their full development, no further increase of capacity is required, and the bones become consolidated to afford the requisite protection and security to the extremely delicate organ they invest.

This gradual consolidation of the cranial case forms an exceedingly striking and beautiful arrangement, when viewed more attentively, in relation to the growth and development of the brain. In very early life, whilst the brain is undergoing a very rapid growth, there is a correspondingly rapid increase required in the extension of the cavity of the cranium. To effect this, the cranium grows through the medium of a great number of individual and isolated centres, each of which, spreading itself out in certain and appropriate directions, produces a very rapid increase in the general dimensions of the cranial cavity. As the demand for this rapid extension becomes diminished, by a more gradual development of the brain, the number of individual osseous centres of growth becomes proportionately decreased by the union or consolidation of contiguous portions of

bone. Thus, to take again as examples, the frontal and occipital bones ; during the earlier periods of the development of the brain, when it is increasing rapidly in size, the former consists of two, and the latter of four, distinct and isolated portions, each portion forming an independent centre of growth. These independent and isolated masses afterwards unite, so as to form single bones ; and the same consolidating process continuing between the separate bones themselves, the power of extension of the cavity of the cranium becomes gradually diminished, until at last, when the complete development of the brain has been accomplished, and its maximum size has been attained, no further increase of cranial capacity is required, and the bones become consolidated into a hard unyielding case, incapable of any further normal expansion.

That the true object of the great number of isolated portions or centres of bone, observed in the fœtal skull, is to produce a rapid extension of the cranial capacity, cotemporaneously with the rapid growth of the brain at this period, is fully confirmed by the appearances presented by the cranium, in cases of hydrocephalus. In these unfortunate subjects there is a demand for a greatly abnormal and comparatively rapid expansion of the cranial cavity, which, in a considerable measure, is effected by the large development of numerous islets or insulated masses of bone, known in anatomy as the *ossa Wormiana*. Each of these, growing from its own centre, produces such a rapid extension of surface that, until consolidation takes place, the cranium is adapted to the rapidly increasing bulk of its contents.

Amongst the osseous portions of the cranium, that are regarded and described by anatomists as constituting separate bones, the sphenoid and the occipital

are those that become first consolidated or united together. But this consolidating process, which here commences between what are conventionally called the cranial bones, is only a continuation of that which has been already taking place between the previously separate portions of the bones themselves; and which, still proceeding, finally solidifies the cranial case into a continuous, unbroken, or uninterrupted layer of osseous tissue.

The reason of this early union between the sphenoid and occipital seems probably connected with the following considerations. Being situated in the centre of the skull, their timely consolidation is required to enable them, in acting as a central or fixed point, to determine the proper direction of growth of the surrounding cranial bones. And their line of union being seated at the basilar process, the period of their consolidation presents also a bearing in reference to the maximum growth or full development of the medulla oblongata. This portion of the nervous centre, although simple in its function, yet, being associated with the processes of respiration and deglutition, is most essential to the persistence of animal life. It consequently early attains a state of completion, as regards its growth and development, and therefore correspondingly early necessitates a state of completion or of consolidation of the portion of osseous structure over which it rests.

The limits of these Lectures will not allow me to attempt to trace to you the line of order in which the union of the rest of the bones takes place. Such order is, I have no doubt, determined by definite physiological relations, a careful investigation of which would afford an exceedingly interesting subject of inquiry.

Having thus cursorily directed your attention to the gradual consolidation of the walls of the cranium, and

the relation it bears to the progressive growth and development of the brain; let me next proceed with an investigation into the nature and intention of the various processes which give to the skull its extreme irregularity of surface and complexity of configuration. If we contemplate for a moment the delicate structure of which the cerebral organ is composed; and then glance at the hard, rough, and irregular surface the internal cranial base presents; it certainly would, at first sight, suggest the idea as being far more adapted for injury than for protection to the brain. But if we pause and examine more closely into the relation which these projecting processes bear to the other parts of the cranium, we shall, I think, not only be struck with the beauty of their arrangement, but be convinced of the salutary influence they exert in maintaining the integrity of the brain during the exigences and necessities of everyday life. Rely upon it as an indisputable fact, that nothing in the cranium exists unless designed to carry out some definite intention, or unless formed in reference to some distinct and special object.

In pursuing this inquiry, and adopting, as far as is practicable, some systematic arrangement, I shall engage your attention, first, with the exterior and then with the interior of the cranial vault; next with the internal, and then with the external base; and shall afterwards, before proceeding with the bones of the face, advert to those exceedingly interesting changes which are brought about by the final completion or the full development of the sphenoid bone.

Between the superciliary ridges of the frontal bone of the adult skull, is a more or less well-marked prominence, termed the nasal eminence, which corresponds

with and is produced by the development of the frontal cells or sinuses. These sinuses constitute accessory cavities to the nasal apparatus, and are formed at that particular period of life when the sense of smell is attaining its highest state of functional activity. They remain entirely undeveloped during infancy and early youth; and it is my impression, from a careful examination of the numerous skulls belonging to the Hospital Museum, that they do not commence to make their appearance until fourteen or fifteen years of age, or even in many instances at a still later period than this. They certainly are not developed at anything like so early an age as is usually credited. Here, for example, is the skull of a youth, as near as I am able to ascertain, of about thirteen years old; and from the section that has been made, you will observe there is not yet the slightest vestige of a frontal sinus. Here is the frontal bone of another skull, which from the historical data that are attached to it, and from the source whence these data were procured, may be confidently looked upon as belonging to the age of eighteen. A portion of the anterior plate of bone, between the superciliary ridges has been removed, and the frontal sinuses are observed in an exceedingly incipient or rudimentary condition. Passing still onwards, in point of age, we have before us a third skull; that of an adult, of about twenty-two years of age. The frontal cells have been exposed in a similar manner to the last, and, as you notice, present the appearance of considerable sized cavities. I believe, however, that they do not remain stationary even at this age; but that they still continue enlarging until a period of fully-attained maturity of adult life.

From the undoubted functional connexion of these sinuses with the nasal organ, it is not difficult to understand why they should be absent in early life, nor to appreciate why, at a later period, they should be developed in anticipation of those higher functional endowments, which the nose acquires an an olfactory and respiratory organ. But these sinuses do not form the only accession that is made to the nasal apparatus, whilst it is thus acquiring an increased state of perfection as an organ of smell, for there are other cavities connected with the nose, namely, the antrum of Highmore and the sphenoidal cells, which, like the frontal sinuses, remain undeveloped during early life, when the functional capacity of the olfactory organ is comparatively less delicate and acute.

On examining different specimens of adult crania, the extreme diversity or irregularity observed with regard to these sinuses, constitutes an exceedingly curious and striking object of consideration. Sometimes they are altogether absent ; occasionally there is but one solitary cell ; oftentimes there is a single small cell on each side, whilst at other times they form fair-sized cavities—in some instances symmetrically disposed on the two sides of the median line, but more often exceedingly irregular both in outline and dimensions. They are sometimes so largely developed as to extend upwards for nearly the whole distance of the forehead, and likewise backwards for an inch, or even more, along the horizontal plates, constituting the arches of the orbits.

At Plate I. there are six sketches, which show the great variety of aspect these sinuses present. They have been taken from horizontal sections of the frontal

bone, made through the centre of the nasal eminence, and the sinuses are seen as though looking down into them from above. In the upper specimen there are none. In the second there is a solitary cell on the right side. In the third there are two small cells, one on each side of the median line, whilst in the other three, the cells are of much larger size—those in the last being, at the same time, extremely irregular in outline.

The frontal cells are usually described as divided into two lateral sets by a vertical septum of bone. This septum, as you may observe from the specimens on the table, is sometimes complete, and then separates entirely the sinuses of one side from those of the other, but is likewise often incomplete, so that in the dry preparation the two sets of cells communicate laterally with each other. It must not be regarded as a necessary consequence, however, because the osseous septum is imperfect, that in the recent preparation or in the living subject, the sinuses of one side should be directly continuous with those of the other. For instance, in the specimen before you each lateral group of cells is lined by a separate membrane, prolonged from its respective side of the nasal cavity, and these two membranous extensions, becoming adapted in the median line, complete the separation where the osseous septum is imperfect.

The drawing at Plate II. represents the condition of the specimen adverted to. It is a vertical median section of the frontal sinuses in the recent preparation, and shows the membranous extension completing the separation where the median osseous septum is imperfect.

The process by which the frontal cells are developed constitutes a striking illustration of the perfection of

the designs of Nature ; as we are able to trace their formation to the same cause which is increasing the efficiency of the organ to whose function they contribute.

As I have already stated, they do not appear until after a much later period of life than is generally allowed. Before the commencement of their development, the two plates or tables of bone, which constitute the inner and outer surfaces of the cranial case, are placed in close apposition to each other. But the outer plate, being now pushed forwards in a manner I shall directly point out, by the central lamella of the ethmoid under the influence of the development of the sphenoid, and the inner plate retaining its original position in relation with the crista galli and cribriform plate of the ethmoid, the intermediate structure or diploë is extended into cells or cavities varying in size according to the extent to which this process has advanced.

I must needs, for further explanation, anticipate a little of what I shall hereafter have to say concerning the development of the sphenoid. The final completion of this bone does not take place until after the completion or development of the remainder of the cranial bones ; and wedged in, therefore, as it is into the immediate centre of the cranial base, its progressive growth or expansion produces vast and important changes in most of the surrounding parts. The body or centre of the bone is, in early life, solid and comparatively small in size, but it afterwards becomes hollowed out into cells, which, like the frontal sinuses, form accessory cavities to the organ of smell. With this development of the sphenoidal cells, the body of the sphenoid is proportionately increased in dimensions, and the rostrum—a process of bone projecting from its inferior

surface—is also proportionately advanced. Now this rostrum firmly fitting into the vomer, necessarily ploughs onwards this bone, which, advancing in a direction downwards and forwards, likewise carries before it the horizontal or palate plates of the superior maxillary bones, to which its inferior edge is articulated, and thus materially increases the vertical extent of the nasal cavities. In the meanwhile, also, the vomer, in its progression, pushes forwards (as may be understood by reference to the sketch of the vertical section of the skull, represented at Plate III.) the central lamella of the ethmoid, which, in its turn, advances the nasal bones, and likewise the anterior table of the frontal to which they are connected; so as in this way to lead to the formation of the frontal sinuses at one and the same time, and by precisely the same primary cause, by which the nose is rendered more prominent, the nasal cavities more capacious, and the whole more efficient as an olfactory and respiratory organ. Indeed, it is thus seen that the same cause which leads to the increasing perfection of the nasal apparatus leads also to the formation of supplementary or accessory cavities, by which the functional capacity of the organ is again proportionately augmented.

If facts were wanting to strengthen this functional association of the frontal cells, and the relation of their development with the olfactory organ, other considerations might be adduced which tend to confirm the same conclusion. In the skulls of savages belonging to the African race, the nasal eminence is observed to be more prominent, and the frontal sinuses more fully developed than in European subjects. In this specimen, for instance, which is the skull of a man belonging to one of the African tribes, you will notice that the frontal

cells have been enormously developed. They extend fully an inch and a half upwards along the forehead, and an inch backwards over the orbits, and are half an inch in depth, opposite the centre of the nasal eminence, where a horizontal section of them has been made. I do not know, indeed, that I have ever seen them before in so extensively developed a condition. Now, in accordance with this anatomical observation, it is well known that savages—whose instinctive predominate over their reasoning faculties—have their senses, especially that of smell, far more acute than the ordinary civilised races of people. Possessing less reason to guide them, their instinct is proportionately keen, and their senses acute. It is not to be wondered, therefore, that the organs appertaining to these senses should be found in a more efficient or a more highly developed condition.

In the cranium of the flat-skulled Indian, inhabiting the neighbourhood of the Columbia River, the frontal cells present a remarkable contrast to those of the African negro. It is customary with these people to apply artificial compression, during the early part of life, so as to prevent the normal expansion of the summit of the cranium. The result of this strange and unnatural habit is a skull almost flat, instead of highly convex ; and an extremely receding or shallow forehead, with scarcely any development of the frontal cells or sinuses, which, you will observe, are barely traceable in the specimen before me, of which a section has been made. The influence of the compression seems not only to have interfered with, but almost to have completely arrested, the development of these accessory cavities to the nasal apparatus. It would, therefore, form an extremely interesting subject of inquiry to ascertain if these flat-

skulled Indians possessed the sense of smell in a less degree of functional perfection than other human beings. Certain it is, that in ordinary individuals, where the frontal cells exist, but have become invaded by disease, the function of smell is considerably deteriorated.

The frontal sinuses deserve a passing remark in relation to the subject of phrenology. Amongst the speculations of the age, a class of persons, called phrenologists, have mapped out *a portion of the surface of the brain* into a number of irregular-shaped patches, corresponding with what are popularly termed "bumps," on the exterior; and have associated these with certain faculties, sentiments, and propensities. The cerebral tissue lying in the vicinity of the frontal sinuses having been allotted to "Individuality," "Locality," "Time," "Form," "Weight," and "Size." When these sinuses are unusually large, and the nasal eminence correspondingly prominent, it signifies, in phrenological language, that the above faculties of the mind are proportionately developed.

The presence or absence of the frontal sinuses may sometimes form an exceedingly important consideration in a surgical point of view. If, for example, a person be exposed to external violence, and sustain an injury of the forehead, between the eyes or immediately above the nose; such an injury, if in the adult, may be accompanied by even a considerable depression of bone, without leading to any cerebral disturbance; from the anatomical fact that the internal plate of bone is situated deeply, and may still remain intact. But a corresponding accident occurring in the child, where the frontal cells are not yet formed, if similarly attended with depression of bone, would be followed by a most serious and urgent train of symptoms, arising from compression

of the brain ; and would, therefore, require to be looked upon in a much more grave and anxious light.

It sometimes happens, after a severe blow above the nose; or, as the result of a carious disease in that neighbourhood, that emphysema of the forehead takes place ; a symptom which indicates not only the existence of the frontal sinuses, but the existence of a solution of continuity, which has allowed of the escape of air from the nose, to infiltrate the subcutaneous tissue of the forehead. Local emphysema may likewise occur over the mastoid process of the temporal bone, from a similar disturbance of continuity, by disease or accident, of the mastoid cells. The air being permitted to pass from the tympanum through the damaged cells, in this way escapes into the cellular tissue over the mastoid process.

The membrane lining the frontal sinuses being directly continuous with that of the nasal cavities, readily participates in the morbid conditions of the latter, and so accounts for symptoms that are not unfrequently observed to arise in conjunction with disease of the Schneiderian membrane. A person, for instance, from some unusual exposure, catches a severe catarrh. He has a constant and profuse discharge from, and a sense of distension at, the nose. His eyes water ; and nothing is more common than for him to complain of pain, a sense of heat, and even of local tenderness over the forehead, between the eyes. The catarrhal inflammation, in fact, which commenced in the nasal mucous membrane, has extended, by continuity of surface, to the frontal sinuses, and has thus given rise to the symptoms referred to that locality.

The subjects of syphilis, also, occasionally supply another illustration of a precisely analogous nature.

Every one is familiar with the exceedingly curious but strong disposition of secondary syphilis to attack the throat, manifesting itself as a specific ulceration of the soft palate and fauces. In some cases the ulcerative action is arrested, and limited to these parts; but in other less fortunate ones, it may extend forwards through the nasal cavities; or, originally commencing in these cavities, and destroying the septum nasi, it may then proceed by continuity of surface to the frontal sinuses, and there establish a carious action of the forehead, attended with its ordinary and characteristic symptoms. So that, should a patient present himself to your notice in practice, giving the history of a previous syphilitic ulceration of the throat, and having complained of pain and swelling over the frontal sinuses, which is subsequently followed by necrosis of bone, you may be pretty confidently satisfied that the disease of the forehead has not arisen, as it were, spontaneously, but from a direct extension of morbid action along the continuity of surface that is established, through the medium of the nasal cavities, between the throat and frontal sinuses.

In a precisely similar manner may the diseased action of syphilis, modified, perhaps, as it is, by mercury, extend in other directions from the throat, and produce other symptoms, varying with the nature and locality of the structures affected. Thus, after a secondary sore throat, it will not surprise you to meet with pain and swelling over the mastoid process, accompanied with necrosis of the mastoid cells; and, if a syphilitic subject should apply with symptoms referable to a disturbance of the functions of respiration and voice, but not traceable to any structural disease of the larynx, I would strongly advise you carefully to investigate the condition

of the upper part of the pharynx ; for, remember, there is only a layer of mucous membrane and of periosteum interposed between the pharynx and that portion of osseous structure, over which the medulla oblongata is placed ; and disease not only might, but, within my own observation, has extended from the fauces through the basilar process of the base of the skull to the neighbouring cerebral tissue ; producing death preceded by symptoms of disturbance of the functions of respiration and deglutition, and by an alteration of the voice.

Situated immediately above the orbits are the superciliary ridges—prominences of bone which act as a mechanical defence to the organ of vision, shading the eyes from the too powerful rays of light, and protecting the globe from injury in the case of a direct blow received in front of the orbit. The globe, in fact, is so securely placed within its osseous recess that it is extremely difficult, almost impossible, I might say, to injure it by a flat blow, as by that, for instance, communicated with the fairly close fist of the pugilist. You may give what is termed a "black eye," but this is not an injury of the globe, only an ecchymosis of the surrounding tissue.

The arched form of the superciliary ridges in the adult serve with the eyebrows—a row of hairs placed immediately over them—to conduct the drops of perspiration from the forehead down the sides of the cheek and nose, instead of allowing them to flow in front of the eye. You are aware, it is proverbially said and even ordained to be the province of man to labour and obtain his livelihood by the sweat of his brow.* Now, this

* "In the sweat of thy face shalt thou eat bread, till thou return unto the ground."—Genesis iii. 19.

tention would be much interfered with, nay, even almost frustrated, were there not some such means provided, as are afforded by the superciliary ridges and eyebrows, to shelter or protect the eye from the drops or streams of sweat, that would otherwise, in running down from the forehead during hard labour, pass in front of the orbit, and lead to a serious disturbance of vision, as well as to a considerable irritation of the eye.

That the eyebrows and superciliary ridges really do fulfil this serviceable capacity, may be any day practically proved, by watching a workman engaged in some laborious occupation. Such men, partly from their habits, and partly from the nature of their employment—especially in London, where the atmosphere is always so loaded with smoky impurities—may be frequently observed with the surface of their skin, more or less coated with a layer of dirt, which, when they perspire, is washed off and trickles down with the drops of sweat, in the form of an easily recognizable muddy current. So that, if, under such circumstances, the face of these men be examined, the sweat may be readily seen, to have rolled from the forehead down the sides of the face and nose, and not at all in front of the eye.

Above the superciliary ridge, on each side, is a prominence of bone, called the frontal eminence, which, like the analogous prominence connected with the parietal bone, and called the parietal eminence, presents itself in a much more strongly marked condition in the infantile skull, than in that of the adult. On placing the two skulls side by side, and comparing them together, this difference appears exceedingly striking. And, not only are the infantile eminences more conspicuously prominent than those of the adult, but, on examining

them by transmitted light, they are found to form the thickest and strongest part of the bone; whilst on similarly examining the frontal and parietal eminences of the adult, namely, by holding the cranium towards the light, and looking into its interior through the foramen magnum, they are observed as absolutely thinner and more transparent than the surrounding surface. Hence, in these frontal and parietal eminences, there is a marked change taking place during the earlier periods of life—a change which appears to be capable of receiving an easy explanation, and to be connected with an important physiological intention.

If, in the first place, our attention be directed to the skull of infancy, we shall find these eminences, with the external occipital protuberance, which exists as a prominence persistent through life, disposed in the most favourable position for receiving the blow a child's head may encounter in falling to the ground. When, in addition to this, we observe that these prominences form the thickest and strongest part of the bone, and that the osseous tissue radiates in lines of ossific matter from their centre towards the margin or circumference of the bones, which, at this early period of life, are surrounded by a soft membranous tissue;—when, I say, we reflect on these anatomical conditions, and consider that they belong to an age or period of life, at which, from very intelligible causes, the head is more exposed than at any other to external injuries from falls and such like accidents; we cannot fail to recognize in them an exceedingly felicitous design or adaptation of nature.

Children, we know, are extremely liable to falls, and accidental blows of the head especially at the particular period when they are acquiring that more precise com-

mand over the muscular movements of their extremities, which enables them to walk and run with security: and yet, how seldom do we hear of any serious results accruing from these temporary casualties, which are not of occasional or of uncommon, but of everyday occurrence. Now, this immunity from injury, or from serious consequences, during such frequent casualties, seems mostly attributable to the existence of these eminences; which are not only placed, as we have seen, in the most favourable positions for encountering the blow a child's head may sustain in falling to the ground, but likewise constitute the thickest and strongest part of the bones to which they belong. At the same time, from the special arrangement presented by the osseous structure at this particular period of life, the vibrations originated, starting from these central eminences, are conducted along the lines of ossific matter which radiate to the circumference of the bones, where they terminate in soft membranous tissue. So that, in the infant, the vibrations derived from external violence inflicted on the head, instead of being transmitted to distant points over the walls of the cranium, as we shall find take place in the adult, are limited to the particular bone, or segment of the cranium encountering the blow, by the membranous structure attached to its circumference, which offers an effectual barrier to the passage of vibrations, and precludes the occurrence of what is known in pathology as a *contre-coup*.

In the changes that take place during the transition from childhood to manhood, the frontal and parietal eminences become comparatively lost by the gradual expansion and elevation of the surrounding portions or surface of bone. The increasing development of the

cranial base in spreading out the vault or dome, exerts a constant tendency to raise, or, as it were, to lift up the edges of the frontal and parietal bones more than their centres; and in this way leads to the disappearance of their central eminences. Now, at the same time that this alteration of structural configuration is being attained, the muscular system is arriving at a higher state of perfection, and the head is no longer exposed to such frequent accidental blows. Regarded then under such an aspect, the reason of the gradual disappearance of these cranial eminences becomes easily intelligible; for, the head being no longer liable to meet with those temporary concussions to which it was exposed in the child, there is no longer a necessity for providing means to obviate the effects.

Whilst the progressive disappearance of the frontal and parietal eminences is taking place, the cranial bones are, at the same time, becoming united or consolidated together, by the gradual ossification of the membranous structure bounding their circumference. Vibrations, derived from an accident, or injury of the head, do not now terminate at the periphery of the bone that received the blow, but take a new direction and a more prolonged course; and are conducted, as I shall afterwards have occasion more fully to point out, along certain osseous ridges and elevations to special osseous points that project internally from the cranial base, and that are surrounded during life by cerebo-spinal fluid. Arrived at these points, they become interrupted, or broken in their course, by the fluid to which they are communicated, and which, therefore, prevents their transmission to the soft and delicate structure of the cerebral organ.

The external occipital protuberance, in contradistinction to what is observed with regard to the frontal

and parietal eminences, does not, as I have already stated, disappear with the advance of life from infancy to adult age. Its persistence may not improbably be connected with the fact of its being situated on the posterior aspect of the head—a point least capable of being protected from injury.

During the early condition of cranial development, the frontal bone consists of two lateral segments, divided by a median suture which usually disappears at a later period, but sometimes remains distinctly perceptible throughout life. It is extremely important to bear in mind this occasional persistence of the frontal suture, for it might otherwise, perchance, lead you to a serious diagnostic error, in a surgical point of view. Suppose, for example, an adult person is brought before you who has received a severe blow on the forehead that is attended with urgent cerebral symptoms—symptoms of such a nature as to place you in doubt respecting the existence of a fracture, with depressed bone. You give the patient the benefit of this doubt, and you expose the *os frontis* with a scalpel at the seat of injury. But do not hastily conclude, on meeting with a vertical line in the osseous surface, that it is necessarily a fracture, for in this particular case it might not impossibly be due to an unobliterated frontal suture. With a little attention, however, and with a knowledge of the following distinctive characters, you may quickly arrive at a solution of the question. In a suture there is a minutely serrated, or zigzag appearance, which is never observable in a fracture ; and conversely, in a fracture, there is a dark line, formed by a thin layer of blood, occupying the fissure between the fractured surfaces, which is never perceptible in a cranial suture. By such means.

a diagnosis between a fracture and a suture may always at once be easily established.

The anterior fontanelle, which is situated between the frontal bone and the anterior superior angles of the two parietal bones constitutes a portion of the membranous structure existing between the bones of the cranium, at the commencement of extra-uterine life. Its condition, if properly interpreted, often forms an indication of great practical value in the treatment of infants. When the arterial circulation is in a natural state of vigour and activity, the anterior fontanelle is observed on a level with the surrounding parts. If from some cause, the circulation be unduly excited, it is raised, or rendered tense and more prominent ; but if, on the contrary, the circulation be enfeebled, it is lowered or depressed below the contiguous structures. I know, in fact, of no sign, that so clearly and correctly indicates the state of the vital powers of the infant, as this easily recognisable condition of the anterior fontanelle. If on a tactile examination, it be found considerably depressed, it forms one of the strongest marked indications that can be encountered, of feebleness and debility : for it is an evidence of the power at the centre of circulation being inadequate to the supply of the cranial contents with their normal quantity of blood.

There are several foramina that perforate the osseous parietes of the cranium, in order to give exit to veins and thus provide for the free escape of venous blood from the interior of its cavity. Of those which are met with in childhood, some remain permanent through life, whilst others become obliterated on the attainment of adult age. Thus, the outlets in the child for the escape of venous blood from the cranial cavity, are the foramen

cæcum, the sphenoidal fissures, the foramina parietalia, the posterior lacerated foramina, the foramina mastoidea the posteior condyloid foramina, and the foramen magnum. Whilst, in the adult cranium, the foramen cæcum, and usually the foramina parietalia, have become obliterated or impervious.

The existence of such numerous channels for the escape of venous blood from the interior of the skull, is in wise harmony with the peculiar situation under which the cranial contents are placed with respect to the circulatory system. It must be borne in mind, that the brain, an organ of a structure so delicate, and of a function so vitally important, is situated within a hard unyielding case ; which, resisting temporary pressure, does not in the slightest degree afford accommodation to the state of the circulation within. The brain, therefore, being thus confined, and rendered incapable of undergoing temporary enlargement or expansion, would be seriously exposed to injurious compression, on every sudden excitement that increased the action of the heart, and augumented the activity of vascular supply, were there not so free an egress provided for the escape of venous blood.

Regarding these foramina in this point of view, they become invested with considerable functional importance ; and we at the same time obtain an insight into the probable reason connected with the disappearance of those which become obliterated with the attainment of adult age. During the growth and development of the brain, its circulation is more active, and its vascular supply, comparatively larger, than at a later period, when it has arrived at its full dimensions. It is easy to understand, therefore, that a less provision is required in

the latter than in the former condition for the escape of venous blood from within the osseous walls of the cranium.

But, there is yet another point of view, under which the temporary existence of these foramina bears a still more interesting physiological aspect. Children, whose actions are more influenced by sudden emotions, and less governed by the exercise of reason and judgment than adults, often exhibit prolonged fits of passionate crying ; which, produce a considerable, though temporary excitement, or increase of vascular action, and would often place them in imminent peril of their lives, were there not such efficient means provided for the rapid escape of blood from the interior of the cranial cavity under these sudden emergencies. Adults, on the other hand, having higher developed mental endowments, are more able to control their actions, and in some measure to check those fits of passion which lead to such increased vascular excitement of the cerebral organ.

These foramina, then, for the egress of venous blood from the cranial cavity, which are peculiar to a period of youthful life, can, as they have but a temporary existence, only be associated with a temporary function. And this function, as I have just endeavoured to explain, is probably connected with the comparatively greater supply of blood the brain receives during its period of growth and development, and with the paroxysms of sudden excitement, to which the cerebral circulation of the child is so frequently exposed.

The foramen cæcum is situated in close connection with the nose, and the vein it contains communicates with the anterior extremity of the longitudinal sinus. Now, there seems in this arrangement, an explanation for the frequent epistaxis of children, which, I believe, most

generally arises from rupture of a branch of this vein and which may hence be regarded as a conservative measure employed by nature, for relieving the cerebral circulation when in too loaded or plethoric a condition.

The foramina parietalia, which as a general rule, like the foramen cæcum, have only a temporary existence, like it, also, derive the current of blood they give passage to, from the longitudinal sinus. Whilst the other foramina, which remain pervious through life, exclusive of the foramen magnum and great fissures at the cranial base, namely, the mastoid and posterior condyloid, transmit veins that derive their blood from the lateral sinuses.

The superficial position of the mastoid vein on its escape from the cranial cavity, forms a point of importance, when viewed in relation to the practical part of our profession. From its connexion with the lateral sinus, on the one hand, and from the superficial position of its exit, on the other, it furnishes an easily available resource for relieving congestion of the cerebral circulation ; and one which is often resorted to in practice for such a purpose. By the application of leeches or cupping-glasses behind the ears, blood is removed from the structures in the immediate vicinity of the mastoid foramen, thus facilitating the more rapid escape of blood through the mastoid vein from the lateral sinuses, and in this way, directly diminishing the amount of venous tension existing within the cranium.

The ophthalmic vein, issuing from the cavernous sinus, emerges from the cranial cavity through the sphenoidal fissure, and traversing the orbit, reaches the soft structures on the exterior of the face. Its trunk being destitute of valves (like the venous sinuses and

cerebral venous channels in general), it allows of the transit of blood in whichever direction, there happens to be the least obstruction. Under ordinary circumstances, however, blood traverses the ophthalmic vein, in a direction from within, outwards towards the orbit; thus forming another of Nature's provisions, and perhaps the most important of all, under circumstances of sudden and temporary congestion of the brain, for the egress or escape of blood from within the cavity of the cranium.

The absence of valves in the whole of these venous tubes, is a circumstance which is doubtless connected with a wise intention. It enables the blood to pass in either direction, and consequently, greatly increases the freedom of venous circulation; a point of essential importance with an organ, whose functional capacity is so liable to interruption under so slight a disturbance of the balance of its circulating fluid.

There is a tendency, which is not only prevalent amongst students, but even amongst others, to ascribe to the internal jugular veins a more important part than they really perform; or to attribute to them a greater share in the return of venous blood from the brain than they really take; and to regard in a less important light than they really deserve those accessory streams which escape in various points through the osseous walls of the skull. Not only do these accessory streams convey from the brain a considerable portion of its venous blood, under the normal, but also under the abnormal conditions of life; for, when there exists a temporary venous obstruction in the lungs or heart, they constitute the chief and almost only means of escape of venous blood from within the cranial cavity. If, for example, from a voluntary effort, or from some

other cause, the process of respiration be for a short time arrested, we know, as a matter of observation, that the eyes start, and that the face becomes exceedingly red and turgid. The temporary cessation of the respiratory action having produced a stagnation of blood in the capillaries of the lungs, the right auricle becomes gorged, and the whole venous circulation obstructed. The first effects of this obstruction in the lungs and at the right side of the heart, being thrown on the larger vessels in most immediate relation with the right auricle, the circulation in the jugulars becomes early impeded, and the cerebral organ for a time is relieved of its venous blood almost entirely through the medium of those smaller veins (amongst which the ophthalmics hold an especially conspicuous position), escaping through various parts of the cranial parietes to the exterior of the head. These veins being placed at a distance from, and therefore in much less direct communication with, the heart than the jugulars, are less influenced by a temporary engorgement of the right auricle; and, admitting as they do, from the distensible nature of their thin coats, and from the laxity of the surrounding tissues in which they ramify, of considerable dilatation, they are capable, for a limited period, of responding to the increased function that is thrown upon them, and of giving exit to the blood from the interior of the cranium,—a circumstance that accounts for the well-known appearances observed under such conditions.

Where this venous obstruction has existed until death has supervened, as in cases where life has been destroyed by suffocation, strangulation, or by hanging, appearances of the same description, but of a much exaggerated character, are produced; and the starting of the eyes, which forms so prominent, so hideous, and so striking

a feature in these unfortunate subjects, arises from venous distension, in the way I have just pointed out, and not from spasmodic muscular action, as has been by some supposed.

If we reflect for a moment, it appears nothing less than an absurdity in the extreme, to attribute this protrusion of the eyes to muscular spasm. There are six muscles that move the globe, and of these six, two only can possibly have the power of drawing it forwards. How is it possible, then, for these two—the two obliqui—to overcome the other four—the four recti—which, compared even individually, are of far superior strength; and which, during a state of spasmodic action, would be converted into powerful retractors. General spasm, therefore, of the muscles of the eye-ball, would, instead of protruding it, unquestionably retract it. But, it is not only from such an *à priori* consideration that we need arrive at such a conclusion, for actual observation can supply evidence of an equally conclusive nature. During that truly formidable and fearful disease, tetanus, the progressive symptoms may be watched from day to day, or from hour to hour, as the disease advances in its onward strides, and successively implicates nerve after nerve, of the cranial and spinal systems. Now, immediately that the moto-ocular nerves are brought into subjection to its baneful influence, the globes of the eye become powerfully retracted, so as to give to the orbit that shrunken appearance that forms so characteristic a feature in the expression of these unhappy patients.

Besides the numerous outlets that are observed for facilitating the escape of blood from the interior to the exterior of the head, and which tend to obviate the injurious effects of a temporary obstruction to its return

through the jugulars, there is another natural arrangement which I shall allude to here, as it forms so wise and beautiful an adaptation for counteracting the effects of pressure during a temporary state of cerebral congestion. What I refer to, is a compensating medium in the form of a fluid—the cerebro-spinal fluid—which, within certain limits, accommodating itself to the amount of blood contained within the cranium, maintains a constant equilibrium in the degree of pressure to which the cerebral mass is subjected. Any augmentation in the quantity of blood within the cranial cavity, would necessarily exert an undue pressure on the brain, were there not a corresponding displacement of cerebro-spinal fluid into the vertebral canal, to counterbalance by its decrease the increased space occupied by blood. This escape of cerebro-spinal fluid from the cavity of the cranium, into that of the vertebral canal, is permitted by an equivalent displacement of blood, from the immense spinal plexus of veins which surrounds the outer membranous investments of the cord, and which seems arranged in special reference to this particular object.

The extent to which this compensating power of the cerebro-spinal fluid can be exercised or the limit of its capacity of displacement from the cranial cavity, is sometimes well illustrated in cases of apoplexy, where the blood has found its way into the ventricles of the brain. In such instances it occasionally happens that the blood coagulating after its effusion, forms a mould of the space it occupied, and thus gives a precise indication of the exact extent to which it has reached in its progress towards the vertebral canal. In this pathological specimen on the table before me, we have

a preparation of such a description. You will observe that the blood having made its way into one of the lateral ventricles, passed from thence through the foramen of Munro into the third ventricle, and from the third ventricle along the *iter a tertio ad quartum ventriculum* into the fourth ventricle, where its progress was arrested by the incapacity of the cerebro-spinal fluid to admit of further displacement. Up to this point, the expulsion of blood from the spinal plexus of veins had accommodated, or given space for the escape of cerebro-spinal fluid from the ventricles of the brain into the vertebral canal; but as soon as the limit of this compensating capacity was attained, the continued effusion of blood then began to exert an undue pressure on the cerebral mass, which at first disturbed, but afterwards completely arrested its functions, and with these, the functions of life also, immediately that the influence of the compression reached the medulla oblongata—the portion of the nervous centre, associated with the processes of respiration and deglutition.

At present I have only *assumed* that, under the augmentation of the normal amount of blood within the cranium, an escape of cerebro-spinal fluid takes place into the vertebral canal, and that this is here accommodated by an equivalent displacement of blood from the spinal plexus of veins. But it is not difficult to show, by actual experiment, the truth of this statement; and I do not know that any more conclusive evidence can be required than is furnished by these two simple experiments, which I performed, now many years ago, and which I have been since accustomed, annually, to mention in my anatomical course of lectures.

In the first experiment I opened the abdomen of a

subject on the *post-mortem* table, and clearing aside the viscera, removed the bodies of a couple of the lumbar vertebræ, so as to expose the dura mater containing cerebro-spinal fluid. I then forced blood into the interior of the head, by making presssure from below upwards along the course of the internal jugular veins ; and as I did this the dura mater in the lumbar region was seen to rise from the afflux of cerebro-spinal fluid into the spinal canal.

In the other experiment I removed the whole of the viscera from the chest and abdomen of the same subject, without disturbing the head. The blood in the divided branches of the azygos, lumbar, and intercostal veins, formed, as it were, cup-shaped depressions ; but immediately that I applied pressure with the fingers upon the dura mater exposed in the lumbar region, the blood rose and finally flowed out of the above-mentioned venous branches. Just in proportion, in fact, as pressure was made on the dura mater, so was blood forced out from the azygos, lumbar, and intercostal veins.

Having thus entered into a few observations on certain points connected with the upper and outer aspect of the cranium, and having, at the same time, introduced remarks bearing on structures of the interior, functionally associated with those of the exterior, let us next proceed with an investigation of the inner surface of the cranial cavity, commencing with the vault and afterwards advancing to the complicated arrangement presented by the internal base.

On regarding the interior of the cranium as a whole, and on comparing it with the external surface of the brain, the most remarkable circumstance that strikes the observer's attention is, that although the latter

appears at first sight so closely packed within the former, yet, except in an exceedingly limited position, the surface of the one does not correspond with the opposed surface of the other, as you will be able to observe for yourselves from these two specimens on the table before me, which have been taken from nature with the greatest care and accuracy. The one is an exact model of the brain, the other a cast of the interior of the cranium, from which it was removed. You will perceive, on placing them side by side, that whilst in general form and outline they necessarily agree, yet in minute detail they present considerable discordance, except over the roofs of the orbits, where the cast and model precisely coincide; the numerous eminences and depressions on the orbital plates of the frontal bone there corresponding with the opposed surface of the brain. The greatest difference is observable in the middle and posterior divisions of the base, but the dissimilarity between the cast and model on their superior aspect is also exceedingly obvious and palpable.

It is evident, then, that the uneven surface presented by the internal aspect of the cranial vault cannot be intended for adaptation to the cerebral hemispheres, for the elevations of the one do not correspond, either in situation, form, or size, with the depressions of the other; and it becomes, therefore, an interesting, and at the same time an important point, to inquire into the design of such arrangement. Had a mere enveloping case been required to enclose the brain, a smooth layer of bone would have fulfilled this purpose as well as the extremely uneven one that we observe in the adult cranium, and would have been far more simple in its formation. But the brain is an organ

formed of an exceedingly soft and easily lacerable tissue ; and likewise one which plays a most important part in the functions of animal life : it is therefore necessary, the more certainly to secure and maintain its integrity, not only that its enclosing case should be formed of sufficient density or resistance to protect it from external pressure, but that this case or cranium should be constructed in the most perfect form, or fashioned after the most expedient design, for protecing it from the influence of those slight injuries and concussions of the head, which are almost inevitable during the ordinary actions of life. And, insignificant as this uneven surface of the internal aspect of the cranial vault may at first sight appear, yet I think I shall be able to show you, that it has a definite and not unimportant intention, bearing reference to this preservative consideration.

On examining carefully the internal aspect of the dome, we find that the ridges or elevations present a pretty constant and systematic arrangement. Those in the anterior part of the cranium run into each other and converge towards the *alæ minores* of the sphenoid, which, as you know, are continuous with the anterior clinoid processes of the same bone ; whilst those in the middle and posterior parts of the cranial vault, pursue a course towards the petrous portions of the temporal bones ; taking, in fact, pretty much the same direction as the grooves for the meningeal vessels. This arrangement, to a certain extent, is shown in the drawing at Plate III. As these elevations, however, form the thickest parts of the bone, they transmit light much less readily than the neighbouring depressions, and their direction is consequently far more apparent on holding

the cranium between the eye and the light so as to look through its walls and examine it by transmitted light, than could be represented by the pencil of the artist, in a simple drawing of the surface of the internal aspect of the cranium.

Now, these ridges or elevations constituting the thicker and more dense parts of the skull, form better conductors of vibrations than the surrounding bone ; and vibrations, therefore, from whatever cause originating, instead of being diffused over the walls of the cranium, are made to converge and take a definite course to certain points at the base; especially the anterior clinoid processes, which are not in contact with the brain, but lie surrounded by cerebro-spinal fluid ; and the petrous portions of the temporal bone, which are separated from the sphenoid by an intervening membranous substance. The vibrations conducted to these points become here broken or lost, in the one case in fluid, in the other in a soft membranous tissue ; their transmission to the cerebral substance being thereby prevented, as I shall have occasion more fully to discuss at a future period in these Lectures.

The beauty of such an arrangement as is here observed must be admitted to be exceedingly striking, and it becomes the more so, as we study and compare it with the condition existing in the infantile skull. We have already seen, that in the latter, the cranial bones are not united as in the former. They do not even come in contact with each other, being separated by an intervening membranous substance, in which the vibrations arising from a blow or other external influence are completely arrested. As, therefore, from this special anatomical disposition in the child, vibrations terminate at the periphery of the separate

bones, instead of being conducted to certain points at the base of the skull, we might, on these grounds alone, premise the absence of those ridges and elevations which are observed on the internal aspect of the adult cranium. But this need not long remain a matter of doubt or of mere supposition, for on inspecting the interior of the infantile cranial dome, its surface is found perfectly concave and smooth, without even a trace of any of these ridges or depressions. Yet, convolutions exist on the surface of the brain just as in the adult. And if, therefore, supposing for an instant, the elevations and depressions on the internal aspect of the adult skull were for adaptation to the convolutions of the brain, we might naturally look for them also in the infantile skull, the same condition of the brain existing in both cases alike.

Regarding these ridges and elevations, then, as intended for the conduction of vibrations to the centre of the cranial base, where means are provided for intercepting their transmission to the cerebral substance, we see why they should be absent in early life, and why they should be developed at a later period, when the separate bones of which the infantile cranium consists, become united or consolidated into one continuous unbroken surface.

This dissimilarity between the interior of the cranium and the opposed surface of brain, forms, in addition to many others, an exceedingly strong argument against the doctrines of craniology, or the so-called phrenology. To any one who may possess preconceived notions in favour of such a system, let them carefully investigate the facts which anatomy supplies, and, unless completely blind with prejudice, they can-

not fail to find amply sufficient to eradicate all credence in a theory erected on so shallow and so fallacious a groundwork.

Besides the cast and model I have already referred to, and which furnish such convicting evidence against the principles of phrenology, here is another specimen, consisting of an actual preparation, which points also in a similar direction. The convolutions on one side of this brain, you will notice, are full and round, and present a perfectly natural appearance; whilst those on the other side are small and shrivelled up, without, however, any corresponding internal elevation or external depression of the opposed part of the cranial parietes. But, examples of this description are not rare; on the contrary, cases of a parallel nature, showing remarkable variances between the opposed surface of the brain and its enclosing case, are not of uncommon occurrence in the *post-mortem* room of the hospital.

Not only is there the universal discordance that I have alluded to between the surface of the brain and the opposed surface of its investing osseous parietes, when examined in minute detail; but, as we proceed, we shall find that there may exist even a discordance in general form and outline, between the surface of the brain and the *exterior of the head.* These three models in wax, which have been executed with the greatest truth and accuracy, serve to prove what I have just stated. They were taken from the head of a New Zealander, who died a few years since in one of the wards of this hospital. The exterior of the head, you will observe, presents an exceedingly peculiar configuration, being raised along the median line into a

longitudinal promontory, or, as it were, a convex ridge ; whilst the surface of the dura mater beneath, and likewise, in the other model, the surface of the hemispheres of the brain, do not at all participate in this peculiarity, but present a perfectly natural and ordinary appearance. There is, also, another set of models of a similar description on the table, taken from another individual, which likewise illustrate the variance that may exist between the form and configuration of the exterior of the head and that of the brain. How, then, if the surface of the hemispheres of the brain do not correspond with the surface or configuration of the exterior of the head ; how is it possible, I ask, to determine, in detail, as is professed by the advocates of phrenology, the precise form and outline of the former, by a tactile examination of the latter ?

Independently of these facts, relative to the discordance of form observable between the exterior of the head and the corresponding surface of the brain, there is yet another argument which anatomy teaches us, and which is equally as conclusive in controverting the principles of phrenology. If it be the grey matter of the brain that is associated with the faculties and endowments of the mind, or the power of originating thought, as is pretty generally admitted by authorities of the present day, and as enters into the creed of phrenologists ; what is the use of that portion of grey matter, constituting nine-tenths of the whole, situated at the base of the brain and elsewhere, which does not fall under consideration in the system of phrenology, and which cannot by any possibility be estimated or appreciated in the living subject ? We observe the surface forming the superior aspect of the hemispheres,

mapped out and allotted to our various faculties, sentiments, and propensities; but this constitutes only a tenth of the whole surface of grey matter, and that portion which is situated between the convolutions, in the island of Reil, and at the base of the brain, is passed over completely unnoticed by phrenologists: as likewise its thickness, which should form a very important consideration in estimating the whole amount of grey matter present. The folly and absurdity, then, of mapping out a small portion of the surface of the brain, attributing to it special and arbitrary functions, and leaving the remainder wholly out of consideration, must, I am sure, be sufficiently apparent to every unprejudiced observer.

Many other facts of an anatomical character might also be adduced, equally showing the fallacious principles of such a system. For example, the utter impossibility of determining the extent of development of the cerebellum, which in phrenology is associated with the function of amativeness, through the immense mass of muscular tissue, bone, and cerebro-spinal fluid which are interposed between it and the cutaneous surface. Again, the surface corresponding to the posterior lobes of the brain, in phrenology, constitutes the seat of the animal propensities; whilst on tracing these lobes in their evolution through the animal series, we find the degree of their development to bear a direct proportion to the sagacity, or the mental capacity of the individual; and they might almost be described, indeed, as being peculiarly human, and associated, in all probability, with man's highest endowments.

If, now, in proceeding with the internal base of the skull, we first glance at the general form and arrange-

ment it presents; if we direct our attention to the numerous irregularities, and even pointed projections, rising from its surface, and then reflect that on this rough uneven floor is placed one of the softest tissues in the body, does it not seem wonderful, almost miraculous I might say, how so delicate an organ as the brain escapes injury during the varied movements to which the head is subjected. Viewed abstractedly, indeed, under such a light, the base of the skull would at first sight appear especially formed and pre-eminently adapted for piercing, lacerating, and destroying the cerebral tissue, instead of preserving it intact. Examined a little more closely, however, in connexion with the neighbouring parts, we shall find reason to attach to these projecting processes of the internal base an important function—a function having a highly conservative or salutary tendency in the cerebral economy.

I have already shown that the surface of the brain does not correspond with that of its enveloping case, and also that this discordance is greatest in the central parts of the base, where the opposed surfaces of brain and cranial parietes bear but a slight resemblance even in general outline to each other. The question now arises—Upon what cause does this dissimilarity depend? what, in fact, is it that occupies the space thus occasioned? The answer to this question is easily given; for, on dissection, we find a fluid—the cerebro-spinal fluid—interposed between the cranium and the organ it contains, at those parts where the diversity between the two is greatest. So that the brain in fact does not rest on the hard, rough, and uneven surface of the internal base, but on a stratum of fluid, which, acting as a water-bed, prevents the contact of

the cerebral tissue with the projecting processes of subjacent bone.

This at once explains how it is that an organ, constituted of so soft and delicate a structure as the brain, and possessing so important and complex a function — a function so liable to derangement from such slight disturbing causes, should not receive injury, and be pierced or lacerated by the irregular projections from the osseous surface which supports it, during the ordinary movements of the head. Were it not for this bed of fluid—the depth of which is greatest in the middle and posterior divisions of the base, where it entirely prevents the cerebellum from coming in contact with the occipital fossæ, and the central parts of the cerebrum with the opposed surface of the cranial base—I say, were it not for this interposed bed of fluid, we might not unfairly presume that every movement of the body, as in running, jumping, and such like, would be severely felt in the brain, and would there produce much serious disturbance of its functional capacity, if not absolute lesion of its structural integrity.

From these considerations, it is evident, that the cerebro-spinal fluid performs a most salutary office in the cranial system; and the study of its varied relations becomes a subject of the deepest interest and importance, and one well worthy a more attentive consideration than is usually bestowed upon it. We have already referred to the important part it plays, by its capacity of displacement into the spinal canal, in obviating the effects of pressure on the cerebral organ, and thereby counteracting the interruption of its functional activity, during a temporary state of congestion,

or of plethoric embarrassment of the cerebral circulation. We have just alluded to its almost equally important function, in removing the brain from the hard irregular surface of the subjacent bone, and in substituting a soft elastic bed for its support, so as to preserve its structure intact during the ordinary movements to which the head is subjected in the varied actions and casualties of life. And on pursuing our inquiry into its functional associations, we find, that it yet presents another important consideration, that of preventing the transmission of vibrations from the osseous parietes of the cranium to the easily lacerable texture of the cerebral tissue.

I have previously stated, that on examining the interior of the adult cranium by transmitted light, certain ridges or elevations of bone are observed connected with the internal osseous plate ; which, although pursuing an irregular and tortuous course, yet may be distinctly traced to converge towards the anterior clinoid processes of the sphenoid and the petrous portions of the temporal bones. In accordance with this anatomical arrangement and with the physical laws of nature, vibrations derived from a slight blow, or other external influence ; instead of being diffused over the walls of the skull, meeting on the opposite side, and producing the injurious effects of *contre-coup ;* travel along these ridges which, by virtue of their greater thickness and solidity, form better conductors of vibrations than the surrounding parts, and converge (*vide* the arrows inserted in Plate IV.) towards the anterior clinoid processes, and the petrous portions of the temporals, where they terminate in the following manner.

The anterior clinoid processes lie surrounded by ce-

rebro-spinal fluid, without having, as I have already said, the slightest degree of connexion with the superimposed brain. And the vibrations conducted to these points, become here broken or lost in this fluid, which thereby intercepts their transmission to the tissue of the cerebral organ.

The petrous portions of the temporal bones, being separated from the basilar process by an intervening layer of soft or membranous structure, the vibrations conducted in this direction become here also completely obstructed without transmission to the brain. Were it not, indeed, for this interception to the transmission of vibrations, by the interruption to the osseous continuity between the petrous portions of the temporal bones and the basilar process of the sphenoid and occipital, the latter would be constantly exposed to serious concussions, or even the chances of fracture, at the angle or point of collision of the vibrations travelling along and meeting from each petrous portion of the temporal.

The vibrations which are continually being transmitted to the cranial parietes from the spinal column, during the ordinary movements of the body, starting from the condyles of the occipital bone, probably pursue the directions indicated by the arrows in the drawing at Plate IV. Some, passing by the dense ridge of bone that extends from the occipital condyle to the jugular process, reach the petrous portion of the temporal, whence they are conducted to its extremity, where they terminate in the membranous structure already referred to : others travelling along the basilar process of the occipital and sphenoid, arrive at the posterior clinoid processes, where they are intercepted or lost in the cerebro-spinal fluid, which surrounds these

as well as the anterior processes : whilst the remainder, being transmitted, as indicated by the dotted arrows at Plate IV., by the ridge of bone situated at the side of the foramen magnum, attain the internal occipital protuberance to be thence distributed along the elevated margins of the longitudinal and lateral sinuses.

The posterior clinoid processes also constitute projecting points of bone for the termination of a portion of the vibrations derived from a blow on the posterior part of the head. Suppose, for instance, that a person receive a blow in the neighbourhood of the posterior occipital protuberance : some of the vibrations thus generated, travel along the ridges of bone which exist on either side of, and form the margins of the groove for the longitudinal sinus, and terminate in front at the *crista galli* of the ethmoid, as I shall afterwards have occasion more particularly to describe : others, as shown by the arrows in the drawing already referred to, take a direction along the prominent margins of the lateral sinuses, and reach the petrous portions of the temporals, at the extremities of which they terminate, as before mentioned : whilst the others, pursuing a course along the internal occipital crest, and arriving at the foramen magnum, pass by the ridges of bone situated on each side, to the basilar process, whence they proceed to the posterior clinoid processes, to terminate in the surrounding cerebro-spinal fluid.

That the statements I have just made concerning the conduction of vibrations from the walls of the cranium along certain definite channels to points of bone at the centre of the base, where they terminate without injury to the cerebral and surrounding structures ;—I say, that what I have just stated on this

point, is not merely hypothetical, but really does take place in the living subject; is strongly supported by the phenomena that are sometimes observed in cases of fracture of the cranial base For example, I have known it to happen, that a person having been exposed to external violence, which has led to a fracture of the base of the skull, and feeling pretty well a few days after the accident, has expressed a desire to get up and leave his sick chamber, which his medical attendant has been indiscreet enough to allow him to do, or which he has done of his own accord, without the knowledge or consent of his medical adviser. After moving and walking about, however, for a short time, he has soon complained of headache, has been attacked with sickness and vomiting, afterwards has had confusion of his ideas, and, finally, has fallen into a state of unconsciousness, in which after three or four days he has expired.

The explanation of these symptoms, I believe, to consist in the interference which the fracture has produced, or the interruption it has occasioned to the natural course and termination of the cranial vibrations. During the time that the patient remained quiet in bed, there were no vibrations to disturb the injured parts, but as soon as he began to move and walk about, the vibrations, which were thus occasioned, instead of being conducted onwards to their natural points of termination at the centre of the base, were interrupted in their course at the line of fracture; thus setting up irritation, with perhaps slight laceration of the surrounding soft structures, and leading to those serious consequences which ended in a fatal termination of the case.

Not only does there exist this special arrangement in

the cranial economy for the conduction of vibrations to certain points at the centre of the base, where they become arrested without injury to the neighbouring structures; but these same vibrations, which, as we have just observed, produce such pernicious effects when diverted from their natural course, absolutely serve a significant and even salutary intention in aiding the venous circulation, whilst pursuing their normal transit along their ordinary channels of transmission. Thus, the direction in which the vibrations travel, is, for the most part, the same as that of the venous blood in the cranial sinuses. For instance, the vibrations generated during walking and such like movements of the body, starting from the occipital condyles, and travelling along the basilar process, and also along the petrous bones, pursue the same direction as the blood in the inferior and superior petrosal sinuses, the circulation of which they thus materially aid or promote by the momentum derived from the continued series of small impulses they communicate.

The vibrations, in this manner, facilitating the circulation of venous blood in the cranial sinuses, serve as a compensation for those accessory influences, derived from muscular action and the pulsations of a contiguous artery, which exist in the extremities, and other parts of the body, to accelerate the onward current in the neighbouring venous tubes. They, in fact, seem to aid another arrangement presented in the cranial economy, and adapted for a similar purpose, which I shall here proceed to refer to.

The carotid artery, on its entrance into the interior of the cranium, and whilst pursuing its serpentine course to arrive at the anterior clinoid process, passes through

the cavernous sinus—a sinus situated on each side of the body of the sphenoid. That an artery should thus actually traverse or pass through a venous sinus, and that it should lie, as it were, bathed or immersed in a lake of venous blood, certainly forms a striking and peculiar arrangement, and one which we do not observe presented in any other part of the human body. Such a peculiar relation between the venous and arterial system, as I have just pointed out, is doubtless not without some wise and designable end, and therefore deserves a careful inquiry into the effects it is likely to produce.

In other parts of the body, especially in the extremities, there are, as I have already observed, certain accessory influences for accelerating the venous circulation, which do not exist in the interior of the cranium. For example, during the ordinary movements of the different parts of the frame, which are so constantly taking place, there is with each muscular contraction a compression of the adjacent venous tubes; and, as these vessels are furnished with valves, disposed in such a manner as to prevent the retrograde course of blood, it is obvious that the successive muscular contractions, by the compression thus exerted, constantly tend to urge onwards the fluid contained within these venous trunks, and in this way to accelerate the venous current in its transit towards the right side of the heart.

In the extremities, also, each principal artery is usually accompanied by two veins, lying in close contact with it, and placed one on each side. Now, each arterial pulsation must necessarily communicate an impetus or momentum to the blood circulating in the accompanying veins, and as the blood can only travel in one direction, on account of the existing valvular arrange-

ment, the influence of the communicated impetus will be, like the influence of muscular action, to accelerate the progress of venous blood towards the right side of the heart.

After these considerations we are now prepared for the explanation of the relation observed between the carotid artery and cavernous sinus within the cranium. The object of such a relation seems to be to act as a compensation for the accessory forces that elsewhere exist, and to facilitate the circulation of blood in the cranial venous channels communicating with the cavernous sinus. The position of the carotid artery within the sinus, is analogous, in a functional point of view, to what I have stated concerning the arteries of the extremities and their *venæ comites*. But, it is even placed under a still more favourable condition than these for the production of a similar effect; for the walls of the artery being immersed or bathed in the pool or lake of blood constituting the sinus, each pulsation of the arterial tube communicates a considerable impulse to the surrounding fluid, which escapes from its enclosed cavity or sinus in the direction in which it meets with the least resistance, there being no valves in any of the venous channels situated in the interior of the cavity of the cranium.

The pulsations of the carotid arteries in their passage through the cavernous sinuses, thus supply the absence of that accessory influence which the venous circulation in other parts of the body receives from the muscular system. And, the momentum derived from such a continued series of impulses is fully sufficient not only to prevent the stagnation of blood in the cranial sinuses, but to urge it quickly onwards towards the right side of the

heart, in the direction which offers the least obstruction to its progress. If there be congestion of the venous tubes of the interior of the cranium, it then passes, as I have before pointed out, by the ophthalmic veins through the orbits on to the exterior of the face ; where, from the little resistance offered by the surrounding tissues to venous dilatation, it can find room within certain limits for its escape.

I have thus far opened the discussion of some of the relations presented by the arrangement of the internal aspect of the walls of the cranial cavity ; and the remarks that I have even as yet made will, I think, suffice to show you that the processes of bone projecting from the internal surface of the cranial base, instead of being adapted, as would at first sight appear, for piercing, lacerating, and destroying the brain, carry out a wise and beneficent design in the cranial economy : namely, that of receiving vibrations from the cranial parietes and of transmitting them to the cerebro-spinal fluid in which they are immersed ; and in which, therefore, such vibrations are interrupted or lost before reaching the cerebral tissue, thus obviating that disturbance of the cerebral functions, which would be otherwise constantly accruing from the most trivial blow or concussion of the head.

In continuing this subject, I shall proceed with a *more detailed investigation* of the special associations that suggest themselves in relation to the several processes, examined separately, of the internal base ; and in doing this, let us commence with the *crista galli* of the ethmoid, and thence pass in a direction backwards towards the occipital bone.

The *crista galli* consists of a prominent plate of bone,

which is so situated as to prevent the anterior lobe of the brain of one side, from pressing on the olfactory nerve of the opposite, during the lateral inclinations of the head. The necessity of such a provision becomes apparent when we take into consideration the extremely soft and delicate nature of the olfactory nerve—a character it presents to a far greater extent than any other cranial or spinal nerve, and which would render the slightest amount of pressure injurious to its integrity.

Besides the evident protection thus afforded by the *crista galli* to the olfactory nerve, it is further secured by being lodged in a longitudinal groove, or sulcus, on the under aspect of the anterior lobe of the cerebrum ; which, I may observe, is the only longitudinal groove we meet with on the base of the brain.

That the protective influence here referred to, however, does not form the whole intention of the *crista galli*, is rendered obvious by the great strength and thickness it presents. For, if its function were merely to protect the olfactory nerves from pressure, a thin plate of bone would fully answer all that was required. Its strength and thickness, therefore, may be presumed to be developed in relation to some other intention ; and, on searching for an explanation, we find that it forms a fixed point for the attachment of the *falx cerebri*—an exceedingly strong process of the dura mater, that separates the hemispheres of the brain from each other ; and also, that it constitutes one of those projecting points from the internal base, that I have already alluded to, as intended for the salutary termination of cranial vibrations. Vibrations, indeed, converging from a portion of the cranial parietes, are conducted to the *crista galli*, where they become obstructed and lost in the membra-

nous texture of the *dura mater*, to which it is so largely and closely attached.

This connexion of the *crista galli* with the termination of cranial vibrations, receives corroboration from the fact, that a tolerably severe blow on the back of the head not unfrequently leads to an attack of hæmorrhage of the nose. Now, the hæmorrhage in such cases, arises, I believe, from the conduction of vibrations along the ridges of the groove for the longitudinal sinus to the *crista galli*, and from thence to the septum of the nose, with which this process is in direct continuity : some of the small veins in this neighbourhood being thereby ruptured will fully account for the phenomenon that is observed.

The anterior clinoid processes form strong points of bone, that project backwards into the interior of the cranial cavity from the *alæ minores* of the sphenoid. The first idea that suggests itself, with reference to their functional associations, is derived from the anatomical relation they bear to the internal carotid arteries. These vessels, after emerging from the petrous portions of the temporals, ascend in a direction upwards and forwards along a shallow groove that may be noticed on each side of the body of the sphenoid. They then pass towards the cerebral substance, and in doing so are always situated on the inner side of the anterior clinoid processes; which, thus counteracting their tendency to separation during each pulsation, consequently prevent that laceration of their communicating transverse branch, which might otherwise, in all probability, ensue. I have never seen or heard of the internal carotids lying external to the anterior clinoid processes ; and sometimes the design just referred to is still more perfectly carried out by the

transmission of the arteries through complete foramina developed in these processes.

The anterior clinoid processes also form two of those points of bone, connected with the internal base, which in the living subject are surrounded by cerebro-spinal fluid; and which seem specially adapted for the salutary termination of vibrations that are being transmitted along the walls of the cranium.

I have previously, by means of preparations copied from Nature with the greatest care and accuracy, shown you that the various elevations and depressions observed on the internal aspect of the dome of the skull do not correspond with the opposed surface of the brain. It is therefore evident, as I have also already stated, that they cannot be intended for adaptation to the convolutions of the cerebral hemispheres, and, if we examine them with care and attention, we find that they present a definite and designable arrangement: the elevated portions forming undulatory ridges which converge towards certain points projecting from the base of the skull. These ridges, or prominences, no doubt, give greater strength and additional security to the osseous parietes; but, forming the most dense and solid parts of bone, they also act as better conductors of vibrations; and, therefore, as it were, determine the course of their transmission from their seat of origin, in a blow, or otherwise, on the exterior of the head.

The ridges or elevations observed on the inner surface of the anterior portion of the cranial vault, incline inwards towards the *alæ minores* of the sphenoid; of which, the anterior clinoid processes form a direct continuation in a backward direction. These anterior

clinoid processes, not being connected with the cerebral mass, but, as we have seen, being surrounded by, or bathed in cerebro-spinal fluid, constitute an admirable arrangement for deadening or destroying vibrating currents. Vibrations, therefore, originating in the anterior and antero-lateral parts of the skull, from a blow or other external cause, are conducted by these undulatory ridges of bone to the *alæ minores* of the sphenoid, and thence to the anterior clinoid processes, where they become arrested and lost in the surrounding cerebro-spinal fluid, which thus impedes their transmission to the cerebral substance, and thus counteracts those lesions of function, if not of structure, that might be, in the absence of such an arrangement, constantly taking place.

We thus see that these processes belonging to the cranial parietes, when regarded attentively under a functional point of view, become invested with a considerable amount of interest and importance—an interest that strips them of that dry detail, associated with their purely anatomical description, and renders their relations more likely to be fixed in the memory of the student.

The posterior clinoid processes, like the anterior, form prominences from the internal base, which lie surrounded by cerebro-spinal fluid. They constitute the points of termination of vibrations travelling along the basilar process of the occipital and sphenoid. These vibrations seem probably to have two sources of origin: one, from the natural movements of the body; the other, from accidental influences, applied to the posterior parts of the cranium. Of those derived from the ordinary movements of the body, as in walking, running, jumping, *et cetera*, and communicated to the occipital con-

dyles through the vertebral column ; some pursue a direction along the dense ridge of bone that leads to the jugular process, and are from thence transmitted to the petrous portion of the temporal ; whilst others are conducted along the basilar process towards the posterior clinoid processes. Of those, on the other hand, derived from accidental influences, such as blows applied to the posterior aspect of the cranial walls, some are lost in the soft or membranous tissue of one of the processes of the *dura mater*—the *tentoram cerebelli;* some are transmitted (as represented by the arrows in Plate IV.) by the raised edges of the groove for the lateral sinuses to the petrous portions of the temporals ; whilst others are conducted by the median longitudinal crest, observed on the inner aspect of the occipital bone, to the margins of the *foramen magnum*, and thence along the basilar process to the posterior clinoid processes ; at which points, as in the case of those transmitted from the occipital condyles, they become lost in the surrounding cerebro-spinal fluid.

In the skulls of the lower animals the posterior clinoid processes present an extremely varied appearance ; and in that of the squirrel there is an absence of all these projecting points from the internal base. Reasons, there can be no doubt, exist for these differences ; and a careful investigation into this subject, I feel convinced, would offer an interesting field of inquiry for those whose time and acquaintance with the habits of the lower animals fitted them to pursue it.

On the outside of the commencement of the groove, on the lateral aspect of the body of the sphenoid, for the carotid artery, is a small plate of bone, which, although almost constantly present, yet, is not often referred to.

It may be called the carotid process, and it performs the important function of preventing the artery, during its pulsations, from pressing on the second division of the fifth—a nerve endowed with such exquisite sensibility, that the slightest injury or pressure would lead to the production of serious pain and distress. When this small plate of bone, or carotid process, is absent its place is supplied by a membranous arch which carries out precisely a similar intention. The real importance of some such provision is shown by a case reported in Romberg's work on the Diseases of the Nervous System, published by the Sydenham Society.* In this case, the patient suffered from most distressing and frequent paroxysms of facial neuralgia for some years previous to his death; and on post mortem examination an aneurismal enlargement of the carotid artery as it coursed upwards by the side of the body of the sphenoid was discovered, which encroached on the trifacial nerve in the vicinity of the Casserian ganglion.

Near the posterior angle of the *ala major* of the sphenoid is a small foramen—the *foramen spinosum*—which gives entrance to the middle meningeal artery into the interior of the cranium. This middle meningeal artery is distributed over a portion of the *dura mater*, which membrane, as you know, forms the chief source of nutrition to the bones of the head. The middle meningeal comes off from the internal maxillary artery, and consequently derives its blood from the external carotid, which is the vessel for the supply of the parts on the exterior of the head. In ordinary descriptive anatomy

* A Manual of the Nervous Diseases of Man, by M. H. Romberg, M.D. Translated by E. H. Sieveking, M.D. Vol. i. p. 37—45. London, Sydenham Society, 1853.

the middle meningeal receives no notice beyond its origin from the internal maxillary, its entrance into the skull through the *foramen spinosum*, and its distribution to the *dura mater;* but if we examine into its relations, if we search for an explanation of the peculiar course it takes, we shall find that it presents an interest and importance far beyond its mere anatomical consideration.

If it were only for the sake of the supply of a certain quantity of blood to the *dura mater*, the special intracranial arteries, viz., the two internal carotids and the two vertebrals would be amply sufficient for this purpose, and there would be no necessity for the entrance of those small streams that are derived from vessels supplying parts on the exterior of the skull. There must therefore be some obvious and designable end or association in such an arrangement; and this, I think, I shall have no difficulty in convincing you to be the case.

I have previously stated, when describing the arterial system, in a former part of my course of anatomical Lectures, that we can trace, in the distribution of certain vessels, a special association or connexion with certain functions;—the same artery supplying nutritive material to all the parts administering to the same function; in order to insure a cotemporanous and duly proportioned development of the whole. Now, it is to carry out this intention that branches from arteries ramifying on the exterior of the cranium, perforate its parietes and are distributed to the *dura mater* within.

The aggregate or essential purpose of the internal maxillary artery is to build up and nourish those parts directly necessary or accessory to the process of mastication, so that it may be fairly called the *masticatory* artery. From this trunk is derived the middle menin-

geal, which, whilst ramifying in the *dura mater*, gives branches outwards, that supply the squamous portion of the temporal, the *ala major* of the sphenoid, the frontal and the parietal bones ;—those bones, in fact, which contribute to form the temporal fossa, the point of origin of the temporal muscle, one of the chief motor agents of mastication. It also gives a branch inwards, to develope and maintain that other portion of the *ala major* of the sphenoid which gives attachment to the *Pterygoideus externus*—another important muscle of mastication. The middle meningeal artery, therefore, arising from the internal maxillary trunk, may be said to be sent by it into the interior of the cranium to build up and afterwards to nourish that portion of its extent, which, in giving attachment to masticatory muscles, is rendered subservient to the masticatory function.

We see then the explanation of why the internal maxillary artery should send a special and, as it were, devious branch into the interior of the cranium, through the *foramen spinosum;* and we find that it forms but another illustration of the admirable precision and perfection of the works of Nature. That an artery supplying a structure contributing to a certain function, should form an offset from the trunk, that we notice supplying the other structures administering to the same function, is nothing more than we might expect, in order to insure a simultaneous and harmonious progression in the development and nutrition of the whole.

So fully indeed is this intention carried out, that a small artery, also given off from the internal maxillary, enters the cranium through the *foramen ovale*, apparently for the express purpose of furnishing nutritive material

to the third division of the fifth—the nerve that supplies the muscles of mastication. Now, although the intra-cranial portion of the third division of the fifth is situated in such close proximity to the entrance of the internal carotid artery into the skull, yet it is not supplied by this vessel, but, as we observe, receives a distinct offset from the masticatory trunk, so that its nutrition may be maintained in the closest possible relation with that of the other structures administering to the same function.

To obviate repetition, I may here mention that the distribution of the vertebral artery furnish us with another illustration of a parallel nature. The branches of the subclavian seem specially intended to supply the structures connected with the function of respiration.*

* The subclavian has two separate intentions to carry out; one the supply of the upper extremity; the other, the building up and nourishing the parts connected with the function of respiration, as will be seen on examining in detail the branches that arise from it.

The vertebral, besides supplying the parts above-mentioned, is distributed to that portion of the spinal marrow from which the phrenic, spinal accessory, and posterior thoracic—all important nerves of respiration, take origin.

The internal mammary supplies the sternum, cartilages of the ribs, origin of the *pectoralis major*, phrenic nerve, diaphragm, and the upper half, or the respiratory portion, of the abdominal muscles.

The first intercostal artery goes to the first, or the first and second ribs. Now, the first is the only rib that becomes consoli dated to the sternum, and it is of all the others the most important in the respiratory function, as it forms the fixed point for the action of the intercostal muscles in elevating the chest.

The thyroid axis divides into inferior thyroid, transverse, cervical, and supra-scapular. The inferior thyroid builds up the trachea—a tube essentially connected with respiration; and sends

Now, the two vertebrals, which are derived from this trunk, enter the cranium through the *foramen magnum*, and are distributed not only to the *medulla oblongata*, *pons varolii* and *cerebellum*, but likewise to the *dura mater* connected with the basilar process and the inferior occipital fossæ; so as, in fact, to build up and afterwards to maintain the osseous structure, associated with the same function as the above enumerated soft parts. The basilar process, as you know, constitutes the point of support of the *medulla oblongata*—the nervous centre of the process of respiration; and the other portion of the occipital bone supplied by the vertebrals, gives attachment to muscles on the posterior part of the neck, which are employed in the respiratory function.

The petrous portion of the temporal bone, forms the point to which the ridges or *costæ*, on the inner aspect of the postero-lateral parts of the cranial vault are observed to converge. It takes a direction, inwards and forwards, towards the basilar process; from which it is separated by the intervention of a portion of membranous substance.

This membranous union between the basilar process of the occipital and the petrous portion of the temporal, differs from that of all the other bones of the adult cranium; and it is seldom that they ever become united by osseous structure, even at an advanced

a branch upwards (ascending cervical) which accompanies and nourishes the phrenic nerve, and constitutes, in fact, an ascending *comes nervi phrenici*. The transverse cervical supplies the trapezius and the posterior border of the scapula with the muscles attached to it; all of which may be considered respiratory. The supra-scapular supplies the clavicle and scapula; both of which are rendered respiratory by the attachment they give to respiratory muscles.

period of life. The arrangement thus presented is admirably adapted for the arrest of the vibrations, which are communicated to the petrous portion of the temporal, from the postero-lateral parts of the skull, and from the condyles of the occipital bone.

If it were not for this portion of membranous or fibrous tissue that is placed between the basilar process and the petrous portion of the temporal; the vibrations travelling along each petrous bone would, as I have before alluded to, meet at the basilar process; and at the angle or point of intersection would frequently produce sufficient concussion to occasion fracture. The provisions of Nature, indeed, are so perfect, that there is absolutely a sinus—the inferior petrosal—placed along the interval between the two bones. So that, those vibrations, which if allowed to continue onwards, would encounter and lead to such destructive results; are arrested in such a position as to accelerate or favour the transit of blood in one of the cerebral venous channels, by means of the series of impulses thus communicated to the circulating current.

There is a ridge of bone, which is very dense and always present, passing from each condyle of the occipital to its jugular process, where it becomes united to, or continuous with, the petrous portion of the temporal. It serves to conduct the vibrations, that arise from the ordinary movements of the body, and that are communicated to the occipital condyles from the vertebral column, to the petrous bone; whence they are transmitted inwards to its extremity, at which point they terminate in the soft structure that I have just had occasion to allude to.

The transmission of vibrations from the occipital condyles in the direction I have mentioned, accounts for the fracture through the petrous portion of the temporal, that is so often observed, as a concomitant of a severe diffused blow on the top of the head: such as is incurred on falling to the ground from a height.

That this is really an explanation of the cause of the frequency of the fracture occurring through the petrous bone in such cases, is, I think, sufficiently proved by the following experiment, which suggested itself to me, and which I performed a short time since relative to this subject.

Having fixed an ordinary adult skull on a firm support with its vertex downwards and its base upwards, I placed a strong piece or bar of wood across the occipital condyles, and then, by means of a hammer, applied a stout blow as evenly as possible over its centre. The result of this, as I expected, was fracture through the petrous portion of the temporal, the line of fracture intersecting the *membrana tympani.*

By the side of this experiment, let us now place and take into consideration an example of an ordinary accident of the description I have referred to. Suppose, as often happens, that a bricklayer's labourer, falling from a high scaffolding on the top of his head, sustains a fracture of the cranial base, that intersects the petrous portion of the temporal and lacerates the *membrana tympani.* What here takes place, is this: on falling on the top of the head, the body comes with considerable force or violence against the occipital condyles, and the vibrations thus generated—just as in the experiment where the blow was artificially applied—being conducted by the dense ridge of bone to the

jugular process, are thence communicated to the petrous bone, at the point where it is joined or united to the occipital. It is from this point of union between the jugular process of the occipital and the petrous portion of the temporal that the fracture starts; and pursuing the direction in which the vibrations are travelling, it usually intersects and ruptures the *membrana tympani;* —a circumstance that accounts for the escape of blood and cerebro-spinal fluid that so often takes place from the external ear in accidents of this nature.

This escape of cerebro-spinal fluid is a phenomenon of the greatest importance as a diagnostic mark of fractured base; but it must be remembered that it does not always take place *through the external ear;* for where the fracture is in such a position as to leave the *membrana tympani* intact, it finds its way from the tympanic cavity through the eustachian tube towards the pharynx. If, therefore, in practice, you should be called to a person who has sustained a diffused blow on the head, and if you should find hæmorrhage from one or both ears, or, on opening the patient's mouth, should observe blood trickling over the fauces and down the pharynx, and at the same time discover no external lesion to account for such an occurrence, you may be almost certain that you have a case of fractured base before you, and should direct your treatment accordingly. But if, further, you should observe a small quantity of clear fluid running from the external ear or trickling down the pharynx, you may at once regard this, as a pathognomonic indication of fracture of the cranial base.

I do not think there can be now any doubt or question about the clear fluid, which escapes from the ear,

in these cases of fractured base, consisting of cerebro-spinal fluid. In the first place, it does not coagulate on the application of heat, as is the case with the serum of the blood ; and the quantity of fluid, consisting of perilymph and endolymph, naturally contained within the internal auditory apparatus, is so extremely small as to preclude the possibility of its being derived from such a source as this. But an argument that has rendered the subject long since conclusive in my own mind, is founded upon the following observation, to which I submitted a patient presenting the pathological condition in question.

Some years ago, a boy who had sustained a severe injury of the head was admitted into one of the wards of Guy's Hospital. He presented the ordinary symptoms of fractured base, and a small quantity of a thin clear fluid was observed oozing out of one ear. It occurred to me, that if this really consisted of cerebro-spinal fluid, it ought to escape in much larger quantity, on artificially inducing venous congestion of the cerebral circulation. I, therefore, pressed upon the jugulars, and with the other hand forcibly closed the patient's mouth and nose, so as to suspend the respiratory process for a short time, until, in fact, his face became red and turgid from venous congestion. As I had anticipated, in a very few moments the fluid began to flow much more rapidly from the external ear, so much so indeed, that I was quickly enabled in this way to collect even half an ounce of it.

The escape of cerebro-spinal fluid in these cases is easily accounted for. You will remember, I previously stated, that the inferior surface of the cerebellum, and the central parts of the base of the cerebrum,

were separated from the subjacent layer of bone by an interposed stratum of fluid—the cerebro-spinal fluid —which is contained in what is termed the sub-arachnoid space. Now, on dissection, we find that a tubular process of the arachnoid membrane containing cerebro-spinal fluid, accompanies the auditory and facial nerves a certain distance through the *foramen auditivum internum* into the petrous portion of the temporal. And, in cases of fractured base extending across the petrous bone, the line of fracture not only intersects this tubular process of arachnoid, but most commonly, also, the *membrana tympani*, and thus easily accounts for the escape of cerebro-spinal fluid externally, there being a direct communication established, between the external ear and the sub-arachnoid space. When the line of fracture is situated a little more internally, so as to lacerate only the tubular process of arachnoid accompanying the auditory and facial nerves, and not the *membrana tympani;* then the fluid escapes through the tympanic cavity and eustachian tube into the pharynx, and not at all through the external ear. The experiment that I performed on the boy labouring under fractured base, artificially induced congestion of the head, and therefore created an increased pressure within the cranial cavity ; which gave rise to the more rapid escape of cerebro-spinal fluid through the lacerated *membrana tympani* and tubular process of the arachnoid that contained this fluid.

The *medulla oblongata* is placed over the basilar process of the occipital and extends as far as the *foramen magnum.* It is surrounded by cerebro-spinal fluid which prevents it from coming in contact with the neighbouring hard and unyielding osseous surface ;

and at the same time explains, why the *foramen magnum* should be so much larger than the contained nervous centre : the intervening space being occupied principally by fluid.

The *medulla oblongata* does not rest stationary in its position on the basilar process, but moves up and down with the various inclinations of the head ; a fact that is shown by the following experiment.

Having selected a subject from the *post-mortem* room, I transfixed the upper part of the spinal marrow, from behind, with a pointed instrument, immediately below the *foramen magnum*, whilst the head was in a parallel or straight direction with the body. On withdrawing the instrument a little, and then inclining the head forwards on the trunk, I again transfixed the spinal marrow ; and, as you will observe by this preparation, which consists of the parts submitted to the experiment, the two points where the nervous cord was transfixed, are full an eighth of an inch distant from each other ; the inclination of the head having effected a movement of it to this extent, through the *foramen magnum*.

Traversing the inner aspect of the occipital bone in a transverse direction, is a large groove, which lodges the right and left lateral sinuses. On examining this groove, it is a pretty constant occurrence to observe that portion on the right side of the median line, larger than that on the left ; an arrangement which corresponds with, and is obviously adapted to, the lateral sinuses themselves. But, why this difference between the two lateral sinuses ? Why should that on the right side be so frequently larger than that on the left ? Some have assigned as a reason, that it is owing to

the individual lying more frequently on the right side than on the left: the right sinuses, from the effects of gravity, being under such circumstances, loaded with more blood and consequently subjected to more distension than the left. Such an explanation as this, however, depending on such a gratuitous assumption, is totally futile and inefficient. The true cause, indeed, seems to be connected with the anatomical disposition of the two jugular veins, and the more direct course the blood pursues, in its transit to the right auricle, on the one side of the neck than on the other. For example, the right jugular vein takes a direct and straight course from the head to the right side of the heart; whilst the left jugular, after joining the subclavian and arriving at the chest, has to cross over from one side to the other, in order to pour its blood into the right auricle; and, in doing so, necessarily pursues a much more tortuous course. The blood, therefore, being conveyed through a shorter and more direct channel on the right side, arrives at the heart with greater facility, and consequently in greater quantity, than on the left; and thus explains, on physiological grounds, why the right lateral sinus should exceed in size that of the left.

The margins of the groove for the lateral sinuses, being considerably raised by solid portions of bone, renders them better conductors of vibrations than the surrounding parts. But I have before had occasion to advert to this subject, and have already stated that the grooves for the cranial sinuses in general, having their margins raised into ridges or *costæ*, form better conductors than the surrounding surface, and thus transmit vibrations from the circumference of the cra-

nium, to certain points at the centre of the base, where they become interrupted or lost without injury to the neighbouring cerebral tissue. Not only, however, does this apparently insignificant anatomical disposition form a propitious arrangement under this point of view, but, vibrating currents being continually transmitted along the sides of the venous tubes, and in the same direction as the venous currents themselves ; they beautifully contribute to accelerate the venous circulation, by the continued series of impulses they communicate to the onward stream.

Having now completed what I have considered it necessary to say concerning the various processes of the interior of the cranium, and having, as far as lay in my power, endeavoured to point out to you the functional capacity they serve in the cranial economy, let us next direct our attention to an examination of the external base, which, I may premise by saying is likewise provided with numerous processes of bone, that are also associated with interesting and important physiological relations. Everything in Nature being so perfect, and in man so superlatively perfect, we cannot for a moment imagine, however insignificant these cranial processes may seem ;—I say, we cannot for a moment imagine, but that they are developed for the purpose of carrrying out some obvious intention or design. This design, it is true, is in some instances exceedingly difficult to discover, but the fact remains unaltered, and stimulates us on in the inquiry.

The points of bone projecting from the external base are exceedingly numerous. Many of them give attachment to muscles and other soft structures ; but we must not suppose that this is their sole purpose, for

like the processes of the internal base, they doubtless also serve as points for the collection and termination of vibrations transmitted along the external plate of the cranial parietes. I need not, however, refer to them individually in this respect. But, before proceeding further and completing this subject, let us just cast a retrospective glance at the arrangement presented by the *cranium as a whole*, with regard to the transmission and termination of these vibrating currents.

The osseous structure constituting the walls of the adult cranium consists of two plates of bone, separated from each other by diploë—an intervening layer of a highly cellular or porous osseous texture, that forms an exceedingly bad vibratile conductor. The outer plate is provided with numerous projecting points of bone, which, giving attachment to membranous or muscular structures, constitute a salutary arrangement for the arrest of vibrations. Whilst the inner table, which is harder, or more compact, and therefore a better conductor than the outer, is, as we have seen, furnished with a number of dense ridges or *costæ*, that converge from the circumference towards the centre of the base, where they terminate at certain points connected either with a soft tissue or surrounded by cerebro-spinal fluid.

Not only, however, does the cranium present these designable means of security, that I have just been referring to, against the injurious tendency of blows and such like casualities, but its interior, being lined with a continuous layer of membranous tissue —the *dura mater*—this also has the effect of arresting, or as it were damping the vibrations communicated to the osseous parietes. It is well known

that if a bell be lined with some soft material, as for instance a surface of wash-leather, no sound whatever can be obtained on striking it in the usual manner. The metal is now prevented from vibrating with sufficient intensity to produce a sound, from the influence of the bad vibrating medium applied to its surface, to which medium the *dura mater* of the cranium may be justly compared in this respect. So that, indeed, the whole structure and conformation of the cranium seems wisely and intentionally adapted for protecting or securing the delicate and important organ it contains from the injurious tendency of those slight blows and concussions to which the head is so constantly exposed during the ordinary operations of life ; and which, if such means were not provided, might otherwise lead to the most serious and frequent functional disturbances. Two plates of bone, separated from each other by an intervening highly cellular osseous texture ; the outer plate provided with numerous projecting points that give attachment to soft parts, and the inner lined with a membranous layer, and furnished with dense ridges, terminating in the manner I have alluded to, forms the best possible arrangement for intercepting the transmission of vibrations to the cerebral mass ; and, therefore, for obviating those functional or even structural lesions that might otherwise accrue, from the most trivial external influences.

The occipital condyles of the human cranium are thrown much forwards, compared to their position in the lower animals. This, no doubt, has relation to the erect position of man, and is evidently intended as a means towards equipoising the skull on the vertebral column. The head, however, in the adult is still, to

some extent, heavier in front than behind, a fact that is shown by its falling forwards when a person drops off to sleep in the vertical position, or in a sitting posture. The means provided for counterbalancing the increased weight of the anterior over the posterior portion of the head consist of powerful ligamentous and muscular structures placed at the back of the neck. Now, on losing the voluntary control over the muscular system, as on falling asleep, the influence of the muscular force is removed, and the *ligamentum nuchæ* being insufficient alone for restraining the opposite effects of gravity, yields by virtue of its elastic properties, and thus allows the nodding that we observe to take place from napping in the sitting posture, when the head is not reclining against any fixed support.

The *ligamentum nuchæ*, then, is insufficient alone to counterpoise the head on the vertebral column ; but it exerts a considerable influence in this direction, and obviates the necessity of so large an expenditure of muscular power as would be otherwise required in constant requisition. In old age, where the features have become wrinkled and shrunk, where the teeth have fallen out and the alveolar processes have become absorbed, the prepondering weight of the face is materially diminished, and the head is much more closely balanced on the occipital condyles. Now, remark how beautifully these changes harmonise with others that are taking place in the other parts of the system, with the advance of life. As old age arrives, the muscular system undergoes a rapid decline in functional capacity, and the cervical group of muscles, having now lost that vigour and activity they possessed in the youthful and adult period of life, would be no longer capa-

ble of equipoising and controlling the movements of the head, if its anterior portion still exerted the same gravitating tendency that we observed at a previous period. The greater weight of the anterior over the posterior portion of the head depends principally upon the face ; and if a line be drawn extending through the centre of the occipital condyles, it will be found to divide the cranium, strictly so-called, pretty nearly into two equal portions.

The styloid process of the temporal gives origin to three muscles, and is connected in its development with the three organs, to whose functions these muscles contribute, viz., that of the mouth, larynx, and pharynx. In the young subject, it does not exist as a fixed process of bone. Indeed, its attachment or union by osseous tissue to the temporal does not take place until the due proportion and proper relation of the parts with which it is functionally connected—the mouth, larynx, and pharynx—are completed. It not only forms the point of origin of the *stylo-glossus*, *stylo-hyoideus*, and *stylo-pharyngeus* muscles, but it likewise constitutes the fixed point of attachment of the stylo-hyoidean ligament—a ligament that holds suspended the *os hyoides*, which has attached to it the tongue, larynx, and pharynx, and which forms the skeleton or osseous framework connected with the functions of these three organs.

The stylo-hyoidean ligament, therefore, in holding suspended the *os hyoides* or the special osseous framework connected with the tongue, larynx, and pharynx, maintains it in a fixed or steady position, thus enabling the three muscles that are likewise attached to the styloid process, to act with the greatest precision, and under the

most advantageous circumstances on the organs, with which they are respectively connected.

It is at this point, that I shall lay before you what I have to say concerning the development of the sphenoid ; inasmuch, as the numerous and intricate changes brought about in the direction and arrangement of the whole cranial and facial bones, by its growth and final completion, becomes intimately blended with many of the succeeding remarks that I shall have to offer, in the remaining portion of this description of the bones of the head and face.

The sphenoid bone forms the centre, around which all the other bones, both of the cranium and the face, are developed. It is truly and literally indeed a wedge, as its name implies ; and thus impacted or wedged in amongst all the other cranial and facial bones, its progressive development, spreading its different processes out in all directions, plays a most important part ; not only in determining the adult configuration of the skull, but in adapting the final conformation of the organs of the face to the increasing perfection of their associated functions. The mouth, nose, orbits, and pharynx are all more or less directly influenced and cotemporaneously rendered more perfect in form by the complete development of this bone. All those harmonious changes, also, which accommodate the framework of the masticatory apparatus to the increasing number and size of the teeth ; all these, I say, are brought about in a manner I shall presently point out, by the progressive development of this bone. This sphenoid bone, then, considered under this point of view, becomes invested with a degree of interest and importance that is calculated to rivet

the attention, in the study of its exceedingly numerous anatomical relations. By the student, indeed, it is justly regarded as the most complex bone of the body ; and precisely in proportion to the anatomical complexity it presents, are the variety and importance of its functional or physiological connexions.

The primary idea or primary intention of the development of the sphenoid seems chiefly with reference to the masticatory function ; but, in the changes that it produces in the direction of the cranial and facial bones, it may not unaptly be compared, to the scaphoid bones of the carpus and tarsus ; for, in its growth and final development, it effects for the cranium and face, precisely the same object, that these bones effect for the hand and foot.

The scaphoid is the last of the tarsal bones to become ossified ; and in its growth, it not only widens or spreads out the foot, but lengthens the arch ; and increasing its elasticity, thus completes the efficiency of the whole, as an organ of support and locomotion. So again, the scaphoid of the hand, with the trapezium and trapezoid, form the latest of the carpal bones to be ossified and completed, with the exception of the small pisiform bone that seems to act rather as a mechanical defence to the ulnar nerve and artery, than to be developed like the other carpal bones in relation to the movements of the hand. During early life the thumb is as nearly as possible parallel to, or on a level with the fingers, but as age advances, and the development of these carpal bones proceeds towards completion, the thumb is pushed forwards and outwards, so as to be placed more opposite the fingers ; thus materially increasing the efficiency of the hand as a prehensile organ, and adapt-

ing it for those delicate and varied operations, for which it is destined in the adult human subject.

Like these bones, then, the growth and completion of the sphenoid, in spreading out the cranium, and in enlarging the cavities of the organs belonging to the face, supplies the deficiency of the muscular tension, which in other parts of the body has so large a share in determining the final or perfect form of the bones. For example, with regard to the long bones of the extremities, the surrounding muscular tension, acting in different directions, forms a material influence in the determination of their precise ultimate configuration. In the case of the cranium, no such comparable muscular tension exists. Indeed, did it exist, it would rather tend to compress than to expand the cranial cavity. But its absence is supplied by the growth and development of the sphenoid, which, wedged in amongst the other bones, alters their position and direction, and thus influences the ultimate configuration of the whole cranium and face.

On comparing the internal base of the child's with that of the adult skull, there is a most remarkable difference observable in the direction the petrous bones pursue ;—a difference that forms one of the most striking contrasts between the skulls belonging to these two periods. The two drawings at Plates V. and VI., which have been taken from ordinary specimens presented by Nature, illustrate what I have just stated. The drawing, Plate V., is a representation of the internal base of the child's skull. It prominently displays the petrous bones, which take a direction inwards, and only slightly forwards. Plate VI., on the contrary, is a drawing of the internal base of the adult skull. It likewise prominently shows the petrous bones, which now take

a direction less inwards and much more obliquely forwards.

This striking alteration in the direction of the petrous bones, which is in wise harmony with changes taking place in other parts, is effected by the full expansion or complete development of the spinous processes of the sphenoid. As the petrous bones enlarge, each spreading out in all directions from its own centre; the two would necessarily have a tendency, on elongating, to approach each other at the median line, and thus to crush the intervening body of the sphenoid, if they retained their original direction. But, at the same time that the petrous bones are elongating, the spinous processes of the sphenoid are growing and proceeding in a backward direction, and being inserted into the receding angle between the squamous and petrous bones ; they push the whole temporals backwards, and alter the direction of their petrous portions, which, now running more obliquely forwards, can find space for elongating without encroaching on the central parts of the base.

Besides altering the direction of the petrous bones, the development of the spinous process of the sphenoid, fitting in between the squamous and petrous, or the masticatory and auditory portions of the temporal (for the temporal is distinctly divisible into these two portions, which are even separable from each other at an early period of life),—I say, the spinous process of the sphenoid, fitting into the receding angle between the masticatory and auditory portions of the temporal, acts on both alike, and pushes the whole bone backwards, and outwards ; thus giving much increased space for the full expansion of the framework of the parts administering to the masticatory function.

It is to the temporal bones that the glenoid fossæ belong, and these articulate with the condyles of the lower jaw. The temporal bones, therefore, in being impelled backwards and outwards, carry with them the glenoid cavities, and in this way, not only give greater area laterally to the pharynx, but also increase the capacity of the mouth, both laterally and in an antero-posterior direction. The object of such additional capacity is sufficiently obvious: viz., to supply the necessary space required for the increasing size and number of the teeth. In youth there are but twenty teeth, whilst in the adult there are thirty-two, and these are individually much larger than those of early life; the teeth, therefore, of the adult, occupy a greatly extended space, which is in a great measure provided for, by the growth and complete development of the spinous processes of the sphenoid, which, pushing outwards and backwards, the glenoid cavities, at the same time widens and lengthens the cavity of the mouth, just at that period when the molar teeth are appearing. We thus see, how the changes effected by the evolution of the spinous processes of the sphenoid, forms one of the illustrations of the relation that the development of this bone bears to the perfection or completion of the masticatory apparatus.

The temporal bone, on being thrust backwards, carries with it the parietal, which overlaps the portion of the brain associated with the mental faculties, and which, like the sphenoid (the bone that effects this change), is late in arriving at a complete state of evolution or development. The union between the temporal and the parietal is exceedingly secure; the one bone being, as it were, locked into the other by an alternate

overlapping or bevelling of their opposed surfaces of contact. Were it not for such a provision of security, the temporal bone, on being thrust backwards, through the agency of the spinous process of the sphenoid, would glide underneath, or be displaced from the parietal, instead of carrying this bone backwards with it.

The glenoid cavity, not only undergoes the alteration of relative position, with the attainment of adult age, that I just now alluded to; but it also undergoes an alteration of form, that is likewise exceedingly interesting, when compared with the other changes cotemporaneously taking place in the condition of the masticatory apparatus. In the child, the condyloid cavities are quite flat, and are unprotected by any surrounding processes or elevations of bone. The condyles of the inferior maxillary bone, also, have their long *axes* in almost a transverse direction. Plate VII. represents a drawing of the inferior aspect of the infantile skull. The long *axes* of the inferior maxillary condyles, are observed to be situated nearly tranversely. Indeed, if a line were prolonged inwards parallel to the direction of each, they would intersect each other, about opposite the centre of the basilar process.

In the adult skull, on the other hand, the condyloid cavities are not flat, but highly excavated, and guarded or surrounded by elevated processes of bone. The styloid processes exist now, not as processes detached from the cranial base as in the child, but as firmly fixed or consolidated projections, that afford great protection to the inner aspect of the tempero-maxillary articulations. The long *axes* of the inferior maxillary condyles, also, take now an oblique direction backwards and inwards, as shown at Plate

VIII., which is a drawing of the external base of the adult skull. And, if a line were prolonged inwards parallel to the long *axis* of each, these lines would traverse the centre of the occipital condyles, and intersect each other about the middle of the foramen magnum, instead of opposite the centre of the basilar process, as in the cranium of the infantile subject.

These modifications in the form and direction of the articular surfaces of the tempero-maxillary articulation, which, like the alteration in the direction of the petrous bones, produce such an exceedingly striking contrast between the youthful and adult skull, are doubtless effected in relation to the following modifications that we observe, in the nature of the dental organs.

In the infant, there are no molar teeth, and the food is consequently of such a nature as not to necessitate a grinding process. The jaw, therefore, moves simply in a vertical direction, without any rotatory action, and does not require that security against displacement, and that complication in the articular surfaces of the tempero-maxillary articulation, that is developed in later years. So simple, indeed, is the arrangement of the osseous structures entering into the formation of this joint, that, resting on a flat surface without any surrounding prominences, the inferior maxillary bone of the infant, is incapable of dislocation or permanent displacement, and is retained in its position merely by the neighbouring ligamentous and muscular structures.

In the adult, molar teeth are provided, which adapt the masticatory apparatus, not only for crushing, but also for grinding the substances intended as alimentary material. The dental apparatus has now arrived at a greatly increased state of perfection ; and the grinding

action, for which it is adapted, necessitates a rotatory movement of the jaw ; and with this rotatory movement it also necessitates those additional provisions of security in the tempero-maxillary articulation, that are presented to us in the adult skull.

If we refer to the facts supplied by comparative anatomy, instances are easily found which similarly show the adaptation of the form of the tempero-maxillary articulation to the nature of the food, and therefore to the more or less complex degree of masticatory action employed by the animal. In the whale, that gulps its food without submitting it to mastication, the tempero-maxillary articulation is of the most simple description, consisting merely of ligamentous tissue connecting the condyles of the lower jaw to the temporal bones, without either cartilage or synovial membrane. In the dog-fish, which lives on shell animals and thus employs great force in mastication to prepare its food for digestion; the tempero-maxillary articulation is exceedingly perfect, being lined with cartilage and synovial membrane, and the bones locking with great security the one into the other. Here then we have an illustration of two extreme conditions of the tempero-maxillary articulation, dependent clearly on the nature of the food, both animals occupying the same element.

The oblique direction of the long *axis* of the tempero-maxillary articulation belonging to the adult, seems intended to adapt the lower jaw, for the oblique rotatory movement that takes place. During the grinding action of mastication, the lower jaw describes, as it were, a portion of a circle, which considerably multiplies the points of contact between the molar teeth, beyond

what they would have been, if it were merely moved directly forwards and backwards, or simply transversely.

The pterygoid processes of the sphenoid bone of the child, exist in an extremely rudimentary condition ; but, as age advances towards the adult period, they become developed into large and important osseous plates. The reason of this tardy development is sufficiently obvious. In the child there are no molar teeth ; and as I have just stated, it is consequently not intended that its food should be of such a description as to require grinding. Now, as there is no occasion for the full development of the pterygoid muscles—the muscles of mastication especially employed in the rotatory action of grinding—there is equally no necessity for the full development of the pterygoid plates of the sphenoid, as these form the fixed point of attachment of these muscles. As age advances, however, and the molar teeth appear, muscular power is required to enable them to act and grind the food. The pterygoid muscles then increase in size, according to the demand that is thrown upon them ; and with these muscles, the pterygoid plates are correspondingly developed, so as to enable the motor agent to act with the requisite degree of efficiency.

There are two small muscles in this neighbourhood—the *circumflexus* and the *levator palati*—which arise, the one from the sphenoid and the other from the temporal bone. Now, from the extreme proximity of these muscles to each other, it becomes an interesting question, to inquire why they should be so constantly attached to these separate bones. There is, no doubt, some designable end to be attained, which, I think, has reference to the following consideration. I have already

stated, that I believe the sphenoid bone to be specially developed in relation to the function of mastication; and the *circumflexus palati*, in its action on the soft palate, closing the mouth posteriorly as the lips do anteriorly during the reduction of the food, is also subservient to the same masticatory function. It is not surprising, therefore, to find these two structures—muscle and bone—bearing the anatomical relation they do, to each other. The *levator palati*, on the other hand, which raises the soft palate, is associated, not with the process of mastication, but with that of deglutition, and it arises from the portion of the petrous bone, that also forms one of the fixed points for the suspension of the pharynx, and for the attachment of one of its principal muscles—the superior constrictor.

The *circumflexus* and *levator palati* muscles, in proceeding from their origin to their insertion into the soft palate, pass, one on each side of the eustachian tube; to the walls of which, they are intimately attached, so as to keep this tube open, during both mastication and deglutition. When the process of mastication is in operation, the *circumflexus palati* is in action, and exerts a tractile influence on the outer side of the tube; and when that of deglutition is in operation, the *levator palati* effects a similar action on its inner side: so as to maintain the channel of communication between the external air and the tympanic cavity, constantly open during the functional activity, as well as the repose of the surrounding structures. This view of the action of these muscles on the eustachian tube, I have entertained for some years past, and I do not see any sufficiently conclusive reason for abandoning it, notwithstanding that others have attempted to show, that

they close the eustachian tube, instead of maintaining it patent, during the performance of these functional operations.

The palate bone may almost be regarded as an epiphysis of the sphenoid ; for it becomes early united to it, and like it also, is especially developed in relation to the masticatory function. There is a small portion of it that fits in, between the internal and external pterygoid plates, and which assists to form the pterygoid fossa. The complete developement of this portion, as indeed of the whole bone, does not take place until the evolution of the molar teeth, and it seems to have the special effect of pushing the external plate outwards and backwards. It thus not only increases the area of the pterygoid fossa, and thereby the extent of surface for the attachment of the internal pterygoid muscle; but it also, by altering the inclination of the external plate, changes the position of the point of insertion, and in this way the direction of action of the external pterygoid ; thus rendering it more efficient as a rotator muscle, and maintaining it in due relation to the changes of position and direction that are taking place, in the other structures belonging to the masticatory function, with the completion of the dental apparatus.

In its position between the superior maxillary bone and pterygoid process of the sphenoid, the palate bone serves an important purpose in relation to the increasing perfection of the masticatory function. The temporary teeth, which are less in number and smaller in size than the permanent, ordinarily drop away between the age of seven and ten years ; whilst the permanent are not usually completed, until the age of twenty-three. So that, thirteen years or even more, are occupied with the

evolution of the final set of dental organs ; and during this period, as I have already pointed out, great changes are being effected in the position of the neighbouring structures by the growth and development of the sphenoid bone. I have told you, that the full development of the spinous process of the sphenoid, pushes the temporal bone backwards and outwards, which, of course, carries with it the tempero-maxillary articulation. But, at the same time that this change is taking place, and that the *alæ majores* of the sphenoid are expanding and spreading out, or widening the whole of the organs of the face, the vomer is also, through the agency of the growth of the body of the sphenoid and the development of the sphenoidal cells, ploughing the superior maxillary bones downwards and forwards, so as to lengthen the mouth or increase its extent in an antero-posterior diameter. Whilst the temporal bones are thus receding backwards, and the superior maxillary bones advancing forwards, the pterygoid processes retain their original position, and it is therefore obvious, that were there not some bone, whose development was taking place in an equal degree with, or in a special relation to these changes; there would be a vacant space or gap occasioned in the mouth, between the advancing superior maxillary bones and the stationary pterygoid processes. Now, the palate bone it is which fulfils this object, and prevents the gap that would be otherwise occasioned. Like the sphenoid, it is associated with, and developed in relation to, the masticatory function ; and thus introduced in the position we find it, it may be spoken of and described, as the interspheno-maxillary bone.

On the surface of the hard palate, there is a promi-

nent spiculum of bone placed on each side, about opposite the second molar tooth, which only attains its full development, with the completion of the dental apparatus. It obviously serves as a mechanical defence to the palatine nerve and artery ; and being only developed with the evolution of the molar teeth, or at that period of life, when the organ of mastication is best adapted for the comminution or contusion of hard substances ; and consequently, when the nerve and vessel are most exposed to accidental pressure ; it forms another illustration of the beautiful harmony that exists, in the growth and development of the different parts subservient to the masticatory function. On the external surface of the *alæ majores* of the sphenoid, there are also some small ridges of bone, which likewise protect the nerves and vessels, that are here disposed on the surface of the osseous plate, from injurious pressure during the powerful contractions of the temporal and external pterygoid muscles. Were not such an arrangement as this provided, these muscles in contracting and compressing their own nerves, would lead to a paralysis of their own fibres.

All these ridges, or spicula of bone, indeed, to which I have just been alluding, may be regarded as fulfilling the same salutary service for these nerves, that the pisiform bone effects for the ulnar nerve in the palm of the hand. This bone, which is the last of the carpus to arrive at completion, is so disposed in its anatomical relations, and so arranged in its development, as mechanically to protect or defend the ulnar nerve from pressure, at that period of life, when the organ to which this nerve is distributed, and to whose function it administers, has attained its most perfect

condition for the exercise of its grasping or prehensile capacities.

The vomer is a flat plate of bone, which occupies a median vertical position in the nasal cavity, and which, through the influence of the sphenoid, is mainly conducive in determining the final configuration of the nose and mouth. By its inferior border it articulates with the upper surface of the hard palate ; whilst its superior border is adapted for the reception of the rostrum, the azygos process projecting from the under surface of the body of the sphenoid, which, thus fitting into the vomer, forms an exceedingly secure and efficient articulation between these bones. From this anatomical relation, we can perceive how the development of the body of the sphenoid, expanding into the sphenoidal cells and spreading out in all directions, is capable of exerting an influence through the medium of the rostrum ; which ploughs the vomer onwards, in a downward and forward direction, and so alters the relative position of the neighbouring parts, in anticipation of those higher functional attainments acquired with adult age. The inferior border of the vomer, being firmly affixed to the hard palate, its advance necessarily has a tendency to push the superior maxillary bones in a direction downwards and forwards ; so as to increase the capacity of the mouth from before to behind, thereby giving room for the development of the molar teeth ; and at the same time to deepen the cavities of the nasal fossæ, in this way affording space ; not only for the complete development of the turbinated bones, and the extension of the olfactory surface ; but also for the more ready ingress and egress of air through the nasal organ. By its connexion anteriorily with the central lamella of the ethmoid, its

advance also pushes forwards this plate of bone, which, in its turn, elevates the nasal bones, and likewise leads to the formation of the frontal sinuses, in the manner I have previously explained (p. 12).

It is with the attainment of adult age, that the nose assumes a much greater prominence in the face; arising, in part, it is true, from the growth of the special bones belonging to it, but more especially from the changes effected by the complete development of the sphenoid; which, likewise altering the direction of the nasal bones, renders the nasal apertures more efficient in relation to the function they have to perform. In early life, when the food is selected and provided for the youthful subject, by the discretion of others; the nasal apertures are directed, not immediately downwards, but considerably forwards. At a later period, on the other hand, when the nose is required to act as a janitor to the mouth, and to inform the individual of the nature of the food that is being introduced; the nasal apertures are observed to have altered their relation, and to be directed almost completely downwards, so as the more effectually to guard, as it were, the entrance to the mouth.

From these considerations, it appears: that although the vomer plays a most useful and important part in the facial economy, yet, that this part is only of a temporary character, being limited to that period of life, during which the nasal and oral organs are attaining their functional and structural perfection.

That the statement I have just advanced is in strict accordance with actual truth, is fully confirmed by the phenomena that are observed when this bone is removed by disease or otherwise. If, for example, the

osseous septum of the nose be removed or destroyed during adult or old age, it leads to no perceptible change or external disfigurement. But if, on the contrary, such a casualty befall an individual during the period of childhood or youth, or before the development of the nasal organ has been fully accomplished, the nasal bones remain imperfectly advanced, and the nose presents a flattened or deformed appearance.

Many years ago, when visiting the cathedral at Gloucester, I was powerfully struck with the similarity displayed by a portion of its structure, to the position of the vomer in the nasal cavities. In one portion of this ancient cathedral there is an arch, and over it a second, that seems to derive its principal support from a vertical column placed between the two. Now, this is looked upon as an exceedingly elegant and beautiful piece of architecture, but it is only precisely similar to what every one carries about with him in his own nose : the vomer and central lamella of the ethmoid forming the vertical column between the lower arch, or hard palate ; and the upper arch, or nose and cribriform plate of the ethmoid.

The vomer at its inferior border is connected with the line of union, between the horizontal or palate plates of the superior maxillary bones. The expansion of the body of the sphenoid, therefore, into the sphenoidal cells, in advancing this bone downwards and forwards, has a tendency to press down the centre of the roof of the mouth, and thus to keep it rounded like a Norman arch, in order that it may correspond with the upper surface of the tongue. If the hard palate were allowed to assume an angular form, like that, in fact, of the Gothic arch ; there would be an imperfect enunciation of certain letters on the part of the individual,

unless this deviation were rectified, by the introduction of an artificial roof or ceiling, susceptible of co-aptation to the rounded or convex surface of the tongue. Indeed, whilst mentioning this fact at lecture a few years since, a pupil afterwards came to me and said that there were certain letters that he was incapable of perfectly enunciating. On examining his mouth, I found the roof presented an angular or Gothic character; and on supplying an artificial and properly arched ceiling, his defective enunciation was quickly remedied.

The orbit constitutes a deep recess, on each side of the face, the walls of which are formed, not by a single or special orbital bone, but by the union or co-aptation of portions of the superior maxillary, malar, frontal, lachrymal, ethmoid, palate, and sphenoid. The bones of the cranium and face, that thus contribute to the formation of the orbit, are exceedingly numerous, compared with its extent; and this is a point that deserves attention, for I have no doubt, that it constitutes a special arrangement adapted with reference to some wise intention or design.

In such a region as the face, where such important sentient organs are contained in so small a space, it is necessary that the most perfect relation should be established between the growth and development of the several parts, in order to accomplish that beautiful harmony of the whole, that we meet with, as presented by Nature. Hence, therefore, instead of the organ of vision being placed in a cavity formed by a single bone, developed wholly in reference to this one consideration; it is placed in a recess encompassed by several bones, which, whilst they contribute by a portion of their surface to the formation of the orbit, are principally developed in

relation to other purposes, connected with the functions of neighbouring parts. The orbit, indeed, is rather a recess intentionally hollowed out from the surrounding bones, and adapted for the reception of the optic apparatus, than a cavity primarily developed in relation to this sole object, without reference to the neighbouring structures. Again, the number of bones that enter into the formation of the orbit, would enable it to undergo a rapid growth or extension, each bone growing or enlarging around its own centre. And, if the orbit were formed of only one bone, provided with only a few centres of growth or extension ; its enlargement might not be rapid enough, to correspond with the increasing perfection of the other parts belonging to the organ of vision.

Amongst the bones enumerated as assisting to form the parietes of the orbit, there is a small portion of the palate bone, that just shows itself at the extreme posterior part of the orbital floor. I have already alluded to the part that the development of the palate bone plays, in relation to the hard palate ; and its orbital portion seems to be inserted in the orbit to carry out a precisely similar intention, namely, to fill up the gap or vacant space that would be otherwise occasioned by the advance of the ethmoid away from the body of the sphenoid, by the growth of the ethmoidal process of this bone. This is the only reason I can assign, for the constant entrance of this small process of the palate bone, into the construction of the walls of the orbit.

The orbit does not always remain of the same shape or configuration, for there is a most marked alteration of form or outline taking place during the earlier periods of life, or until the attainment of adult age. In the

infantile cranium, for example, the orbit presents a somewhat rounded outline or margin; in that of youth it is nearly oval; whilst in that of the adult it is more or less of a quadrilateral form. Another important change, also, that may be noticed, is, that in the adult the external angular process of the *os frontis* occupies a much more advanced and prominent position than in the youth or child,—a condition that is evidently intended to give increased space for the full development of the lachrymal gland, and likewise to afford greater security to the organ of vision, from accidental injury or external violence.

It is an extremely interesting fact, that all these changes in the form and outline of the orbit, are brought about through the influence of the growth and development of the sphenoid. So that, whilst one portion of the sphenoid is advancing the facial bones anteriorly; whilst another is altering the inclination of the petrous bones, and carrying the condyloid cavities further back, to give space for the molar teeth; the *alæ majores* are spreading out, and expanding or widening the whole of the upper parts of the face, and producing the alterations in the form of the orbits that I have just been alluding to.

The malar bone, which forms the principal portion of the outer wall of the orbit, rests upon the malar process of the superior maxillary bone. Now, this process, in growing outwards and backwards, necessarily carries with it the malar bone. And thus not only are the temporal and pterygoid fossæ deepened, for the full development of the muscles of mastication; but the semilunar edge of the malar bone that forms the outer margin of the orbit, being carried backwards.

increases the extent or range of vision in a lateral direction.

If any one may choose to submit himself to the following observation, he will find that, if he place himself in the erect position and merely employ his cervical group of muscles, he will be able to turn his head on each side, so as to obtain a view of the whole circle, of which he himself forms the centre. But if, now, a small piece of paper be placed at the outer edge of the orbit, so as to advance, as it were, the outer wall, he will at once perceive that, had not the outer semilunar margin been kept back, the extent of lateral vision would have been considerably abridged, and that he would have been unable to have obtained a view of the whole circle around him, merely by the aid of the movements enjoyed by the head and neck.

The retroversion that takes place in the condition of the lower jaw with the arrival of old age, is exceedingly striking and remarkable, when viewed in relation to the other changes, that are at the same time approximating the condition of the old man to that of the child. If we follow, as has been done in the drawings at Plate IX., the form of the lower jaw through the different periods of life, we cannot but notice the similarity that exists between those belonging to the two extremes of age, and the difference that is observable between these, and those belonging to adult life. In the child, the angle between the body and the ramus is exceedingly obtuse; but as life advances a gradual change takes place, so that in the adult a nearly complete right angle is obtained. After this period, and during the decline of life, the angle again progressively reverts to the original condition it presented in the child.

The alteration in the relative position of the body and ramus of the lower jaw, that thus takes place during the onward progress of life, is accompanied with a corresponding alteration in the point of application of the muscular force. In the infantile state, the point of insertion of the elevators of the jaw is placed comparatively near to midway between the fulcrum and resistance; in the adult (from the alteration that has taken place in the direction of the ramus), the point of insertion has approached considerably towards the fulcrum; whilst in old age it has returned to its original position, nearer the midpoint between the fulcrum and resistance.

If we now trace the relation of these changes to the other conditions of life, belonging to the periods of infancy, maturity, and the decline of age; we shall then perceive the admirable design of this arrangement, and the interesting harmony it presents. In the adult, where the muscular system is at its height of functional vigour and activity, the point of application of the force, for the elevation of the jaw, is considerably approximated towards the fulcrum or maxillary condyles. By such a disposition, much power is lost, from its application at a mechanical disadvantage; but for this loss of power, a corresponding rapidity of motion is gained. And thus, at a period of life when the muscular system is at its height of strength and vigour, and when the mouth is required in its greatest perfection; not only as an organ of mastication, but also of speech; the lower jaw is endowed with a greatly increased capacity for rapidity of motion, simply by an alteration in the relative position, between the fulcrum and the application of the power. In the child, on the other hand, where the muscular

system has not yet attained its full development ; and in old age where it has become weak with decrepitude, and where the mouth is required in less perfection as an organ of speech ; there is no substitution of strength for rapidity of motion : and we find the application of the power, situated nearer the midpoint between the fulcrum and resistance ; so as to turn to advantage for the masticatory process the whole of the force that exists.

PLATES.

Plate I.

Six sketches of frontal sinuses, showing the extreme variety of aspect they present. (*Vide* page 9).

Plate II.

Vertical section of the frontal sinuses in the recent preparation, showing the membranous extension completing the separation of the two lateral groups of cells, where the median osseous septum is imperfect. (*Vide* page 10).

Plate III.

Vertical section of the skull, showing how the development of the body of the sphenoid leads to the expansion of the frontal cells. (*Vide* page 12.)

It likewise displays the ridges or elevations connected with the internal aspect of the cranial vault, converging towards the anterior clinoid processes and petrous portions of the temporals—a point having reference to the conduction of cranial vibrations. (*Vide* page 34.)

Plate IV.

Drawing of the internal base of the skull, with arrows inserted to indicate the course of cranial vibrations. (*Vide* pages 42, 54.)

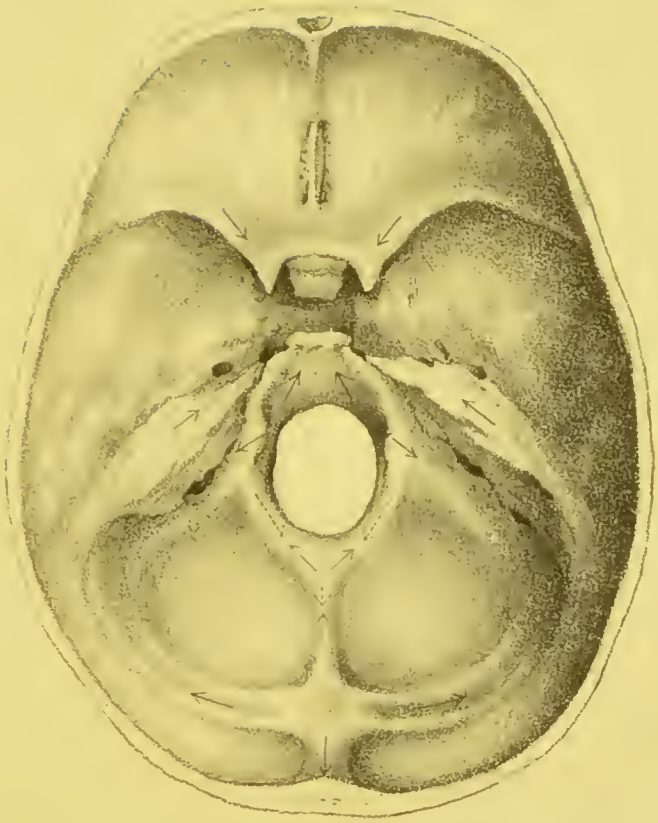

Plate V.

Internal base of child's skull, showing the direction of the petrous bones, which run inwards and only slightly forwards. (*Vide* page 74.)

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Plate VI.

Internal base of the adult skull, showing the direction of the petrous bones, which run very much forwards and but little inwards. (*Vide* page 74.)

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Plate VII.

Inferior aspect of the infantile skull, showing the *almost transverse* direction of the long *axes* of the inferior maxillary condyles and glenoid cavities. (*Vide* page 77.)

r ad Nat^m delt^

Printed by W

Plate VIII.

Inferior aspect of the adult cranium, displaying the *oblique* direction of the long *axes* of the inferior maxillary condyles. (*Vide* page 78.)

Plate IX.

Inferior maxillary bones of the different periods of life, representing the change that takes place in the condition of the angle between the body and the ramus; the similarity that exists between the lower jaw of the infant and of the old man; and the difference observable between these and that of adult life. (*Vide* page 91.)

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